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ALASKAN HEMATOPHAGOUS INSECTS, THEIR FEEDING HABITS AND POTENTIAL AS VECTORS OF PATHOGENIC ORGANISMS

II: THE FEEDING HABITS AND COLONIZATION OF SUBARCTIC MOSQUITOES

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ARCTIC AEROMEDICAL LABORATORY

AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
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FOREWORD

This technical report constitutes Part II of the final report on contract AF 41(657)-333, (Project 8241, Task 824101) with the University of Oklahoma Research Institute, Norman, Oklahoma. Part I was "The Siphonaptera of Alaska." Air Force program monitor is Robert Becker, ALRA, Arctic Aeromedical Laboratory.

Formally, this study concerning the feeding habits, colonization and possible zoonotic relationships of Alaskan mosquitoes was initiated on 1 June 1960. However, several years previous to this were spent in Alaska working on the natural history of tularemia, and the actual beginnings of this study were formulated during these years. Some of the early impressions had to be changed as more knowledge was obtained; however, certain ones have been verified as more detailed data were accumulated. The study continued through May 1964.

Numerous individuals have helped with this research, and it is difficult to give proper credit to all of them. Personnel of the Arctic Aeromedical Laboratory were always enthusiastic in their support of my programs in many ways. Chief among these were Colonel H. F. Currie, Dr. Horace F. Drury, Colonel J. F. Fulton, the late Lieutenant Colonel W. C. Herbert, Colonel Joseph Quashnock, Lieutenant J. Watson, Senior Master Sergeant F. White, Technical Sergeant V. Hicks and Major H. G. Wise. I gratefully and wholeheartedly acknowledge the following research assistants who have worked by my side through intolerably long hours in both the field and the laboratory: R. D. Couser, T. E. Emerson, John Engleman, Miss Ermona McGoodwin, C. J. Mitchell and Dennis W. Trent.

I am indebted to Dan Hopla, Richard Hopla, Dr. L. L. Hufman, Mike Molchan, Dr. William O. Pruitt and Heinrich Springer for contributing specimens. Appreciation is expressed to Dr. Richard Foote and Dr. Allan Stone of the U. S. Department of Agriculture for the privilege of studying the mosquito collection in the National Museum. Dr. F. Gate Clark is acknowledged for special privileges extended to me in allowing me to study long after the Museum was officially closed. I am also indebted to J. R. Vockeroth of the Canadian National Collection for his help and the many courtesies extended me during my stay there. Last but not least, I would like to acknowledge Dr. R. I. Sailer for the conferences in which we both exchanged our ideas concerning the feeding habits of subarctic mosquitoes.

This technical report has been reviewed and is approved.

HORACE F. DRURY
Director of Research

ABSTRACT

Feeding habits of mosquitoes of the taiga and tundra were studied. Greater emphasis was given to those of the taiga, however, because of the longer mosquito season and the greater variety of genera and species present. Using an exposed area of human forearm (54 square inches) and a similar area of shaved rabbit abdomen, biting records were compiled. Mosquitoes were collected by aspirator after the proboscis was fully inserted. Twice as many mosquitoes were collected from the human as from the rabbit, with Aedes excrucians, A. punctor, A. intrudens and A. pionips predominating in the order given. A tower was built, with platforms at 6-foot intervals up to 42 feet, to study vertical distribution and host preference. Domestic chickens, white laboratory rabbits and varying hares, along with empty control boxes, were placed at the various heights. Approximately 80% of the 10,722 specimens obtained were collected in the first 18 feet. The percentages of mosquitoes that were engorged when collected from the bait boxes were as follows: chickens, 18.2%; white rabbits, 70%; and varying hares, 92%. Through field observations and laboratory studies, small rodents (microtines) and passerine birds are not thought significant sources of blood meals, but hares, ground squirrels and larger mammals are. Using insect nets, 46,123 specimens were collected in the vicinity of the tower, both from vegetation and aerially up to height of 6 feet. Only six showed evidence of a recent blood meal. Evidence indicates that most subarctic mosquitoes take but one blood meal, a fact of considerable importance when considering them as vectors of zoonoses. Studies of the natural history of Culiseta alaskaensis indicated that the unfed adult females overwinter close to the ground in dense growths of grass underneath the snow cover where the temperature range is from 16 - 20° F. In the laboratory, C. alaskaensis lived only about one week at 0° F. Chromatographic studies did not reveal the presence of glycerol compounds in the hemolymph.

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I

INTRODUCTION

In Alaska and other northern countries, the blood-sucking insects are represented primarily by two orders: Diptera (flies and mosquitoes) and Siphonaptera (fleas). A comprehensive report on the latter group of insects formed Volume I of this report, and therefore no further mention will be made of them. The most offensive insect species to man and many other mammals are those belonging to the order Diptera, and all the hematophagous creatures in this group, the slightly more than two dozen species of mosquitoes are probably the worst. Lesser offenders are: (1) Heleidae (punkies or no-see-ums) or the genus Culicoides, with six or more described species; (2) Simuliidae (black flies), consisting of approximately 36 described species; (3) Rhagionidae (snipe flies) or two little-known species of the genus Symphoromyia; (4) Tabanidae (horse flies and deer flies), of uncertain number, possibly 24 species.

Since World War II, Alaskan mosquito investigations have provided a thorough insight into the taxonomy of this group. Among other things, these investigations have culminated in "The Mosquitoes of Alaska" by Gjullin, Sailer, Stone and Travis (51). Frohne (see References) has laid the foundation for the bionomics of Alaskan mosquitoes. However, much still remains to be done. Virtually nothing is known about the disease transmission capabilities of boreal insects.

Indeed, prior to this study, little had been learned about their feeding habits; a diligent search reveals a paucity of literature concerning host relationships other than man.

The biting habits of mosquitoes are of vital importance in their potential as vectors of disease organisms. By and large, most of the Alaskan mosquitoes are believed to be single-brooded. This has led many to suggest the possibility of a single feeding. If this were true, it would seem unlikely that insects which feed only once could transmit disease, since none of the insect-borne diseases currently known are transovarian in nature. To transmit disease organisms, an insect must feed at least twice, the last feeding upon man. It must be acknowledged, however, that there are times when it would be possible for mechanical transmission, through interrupted feedings, to play a role in the dissemination of a disease organism. Such a condition would only be a fortuitous one and would not happen with any regularity. Basic to the above-mentioned problems would be studies attempting to colonize subarctic mosquitoes. Until this has been done no study can be interpreted properly.

FIGURE 1

Aedes Mosquitoes Feeding on the Ear of a Laboratory Rabbit
(A) A. excrucians (B) A. intrudens (C) A. punctor

Many boreal mosquitoes engorge so heavily that they are capable of flying only a few feet before alighting to rest upon vegetation.

II

CLIMATE AND GEOGRAPHY

Climate has a direct effect upon invertebrate creatures such as mosquitoes and likely an indirect one upon the terrestrial vertebrate hosts on which they feed. The effect is indirect upon the host by determining the amount and kind of food that is available, as well as the protective cover. These factors largely determine distribution of the terrestrial mammals and also the mosquitoes.

The topography of Alaska exerts a strong influence upon the climate. The coastal mountains of the Alaska Range are not only the highest and some of the most massive mountains in western North America, but also stand directly in the path of warm moist air masses coming in from the Gulf of Alaska. Partly as a result of this, the amount of precipitation in the northern areas is considerably lower than that in southeastern Alaska. The Brooks Range in northern Alaska is lower, less massive, and faces the cold Arctic Ocean rather than the warmer Gulf of Alaska. The intermontane area between these two ranges of mountains is characterized by broad valleys or lowlands through which are interspersed small chains of mountains. For example, the Yukon Flats and the Tanana Valley lie for the most part between 400 and 600 feet in elevation and are drained by the Yukon River and its tributaries. The principal drainage systems within Alaska are shown in Figure 2. In light of the above discussion, climatic factors important to the mosquitoes and to their hosts should not only prove interesting but also provide a better background for understanding the zoogeography of the mosquito. Various investigators have developed concepts attempting to relate such factors as the vegetation and the animal life. For purposes of this discussion, the work of Dice (25), Figure 3, and that of Hopkins et al. (68), Figure 4, are pertinent. These two studies were concerned with different problems, yet it was interesting to observe that the latter authors' "Zone of Continuous Permafrost" closely parallels Dice's Eskimoan Biotic Province; the "Zone of Discontinuous Permafrost" corresponds to the Hudsonian Biotic Province; and the "Zone of No Permafrost" is nearly congruous with the Sitkan Biotic Province. Figure 4 more accurately reveals the distribution of the tundra and taiga than does Figure 3.

Eskimoan Biotic Province

This unique area is characterized by the nearly universal presence of permafrost. The soil thaws in the summer to a depth of 6 inches to 4 feet, depending upon surface material, vegetation cover and exposure. The permafrost is perhaps the dominant ecological feature in the Eskimoan Biotic Province, thereby producing an entirely different flora and fauna, for without it, the Arctic Slope would indeed be a desert. Thienemann (132) first postulated the importance of permafrost in the conservation of moisture in the Arctic. Natvig (103) expounded more fully upon this.

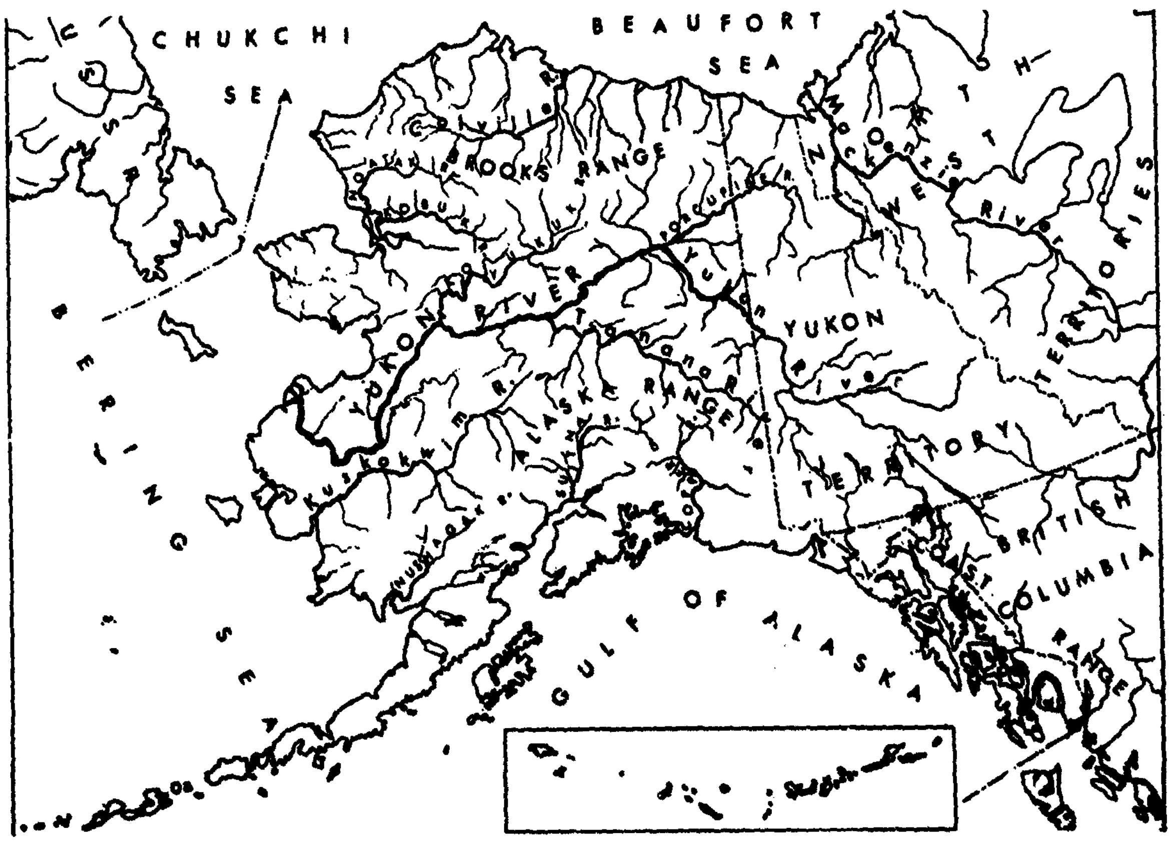

FIGURE 2

Principal Drainage Systems in Alaska

With the exception of the Colville River and its tributaries, most of the rivers flow approximately in a west-southwesterly direction.

BIOTIC PROVINCES OF ALASKA

FIGURE 3

The Biotic Provinces of Alaska (after Dice, 25).

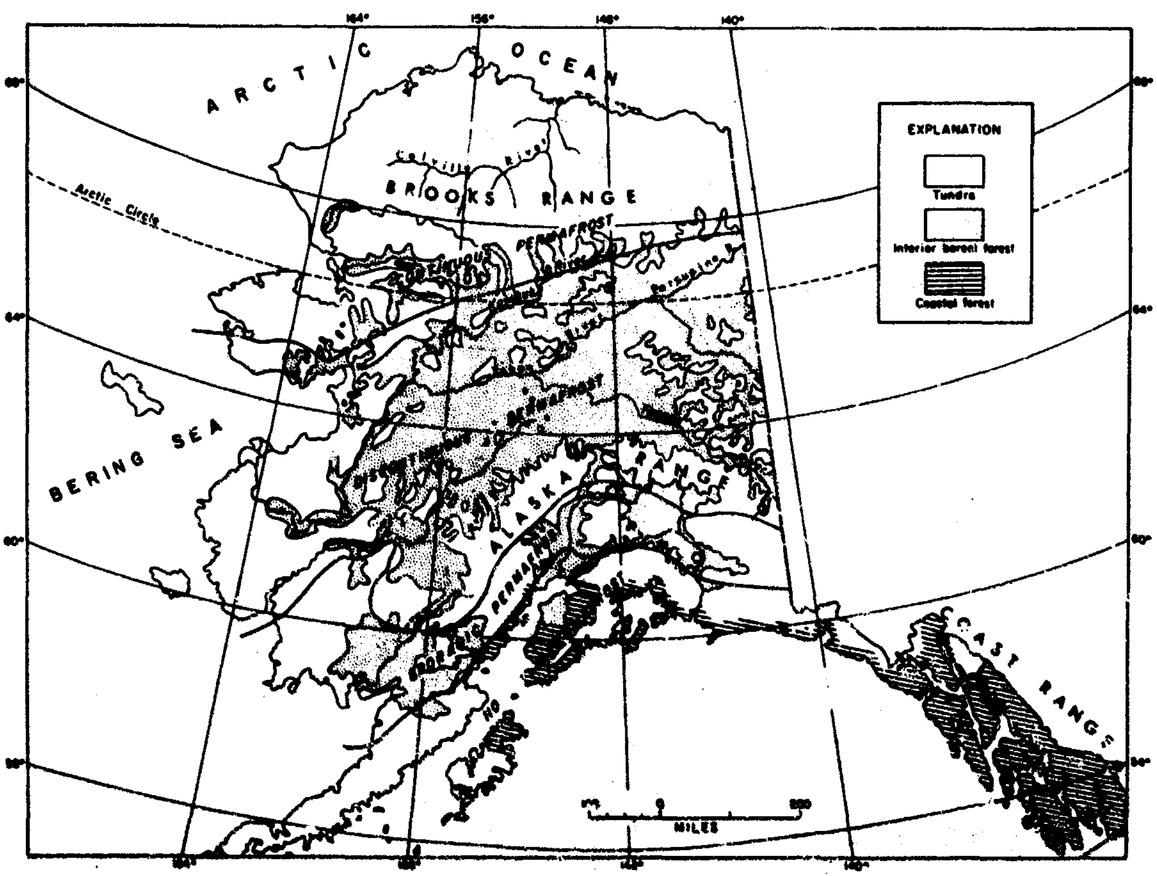

FIGURE 4

The Distribution of Treeless and Forested Areas in Alaska

The treeless areas consist mainly of tundra, but also include glaciers and exposed bedrock (after R. S. Sigafoos, 126).

The vegetation collectively is termed tundra and lies beyond the limit of tree growth although tall willows, alders and scattered poplars grow along the channels of the large streams in the southern part of the region. Tundra vegetation consists primarily of dwarf shrubs, grasses, sedges, lichens and herbaceous plants. As illustrated in Figure 6, the term tundra is applied to a wide variety of vegetation types and is not a good indicator of presence or absence of permafrost. Unless the type of tundra is specified it simply means the absence of trees. For example, Alpine tundra is considerably different from the tundra found beyond the Brooks Range or tree line. Areas of tundra vegetation are interspersed with forested areas throughout most of central Alaska, and both tundra and forest occur in all the permafrost zones, as well as in the zones of no permafrost (note Figure 5).

As an example of the climate, let us consider Umiat. While Umiat is farther inland than Point Barrow, the climate is not remarkably different. The annual mean temperature at Umiat is 10° F, and the recorded extremes are 79° and -57° F. Mean annual precipitation is 5.4 inches, half of which is represented by rainfall during the months of July, August and September. Annual snowfall is approximately 33 inches. Wind is a prevalent feature in this area and causes considerable drifting of the powdery snow that falls during the long, cold winter.

On the Arctic Slope (north of the Brooks Range), the mosquito fauna is limited to one genus and probably five species of mosquitoes. They are Aedes communis (DeGeer, 1776); Aedes hexodontus Dyar, 1916; Aedes impiger (Walker, 1848); Aedes nigripes (Zetterstedt, 1838); and Aedes punctor (Kirby, 1837). I do not mean to imply that these species of mosquitoes are found only in this region of Alaska, for they occur far to the south, some of them being reasonably abundant in the taiga. South of the Brooks Range there is a "fringing" of the taiga mosquitoes extending a short distance north of the tree line, such as I experienced at Anaktuvuk Pass in the summer of 1957, when I found Culiseta alaskaensis (Ludlow, 1906) breeding in rather large numbers around Summit Lake during the latter part of July. Although the habits and method of locomotion of mosquitoes and fleas are not at all similar, it is amazing the number of analogues that can be made in the distribution of these two groups of insects. Figures 5, 6 and 7 illustrates a part of the terrain north of the Brooks Range.

Mammals frequently encountered and more or less characteristic of this Biotic Province follow. Some of these mammals are found to the south in the taiga, thus they cannot be truly characteristic of the province. Others, such as hoary marmot (Marmota caligata) and the Arctic ground squirrel (Spermophilus undulatus) are "characteristic" of the upland "tundra" throughout the montane areas to the south. For further accounts of arctic mammals, the reader is referred to Rausch (115), Bee and Hall (14), and Hall and Kelson (52).

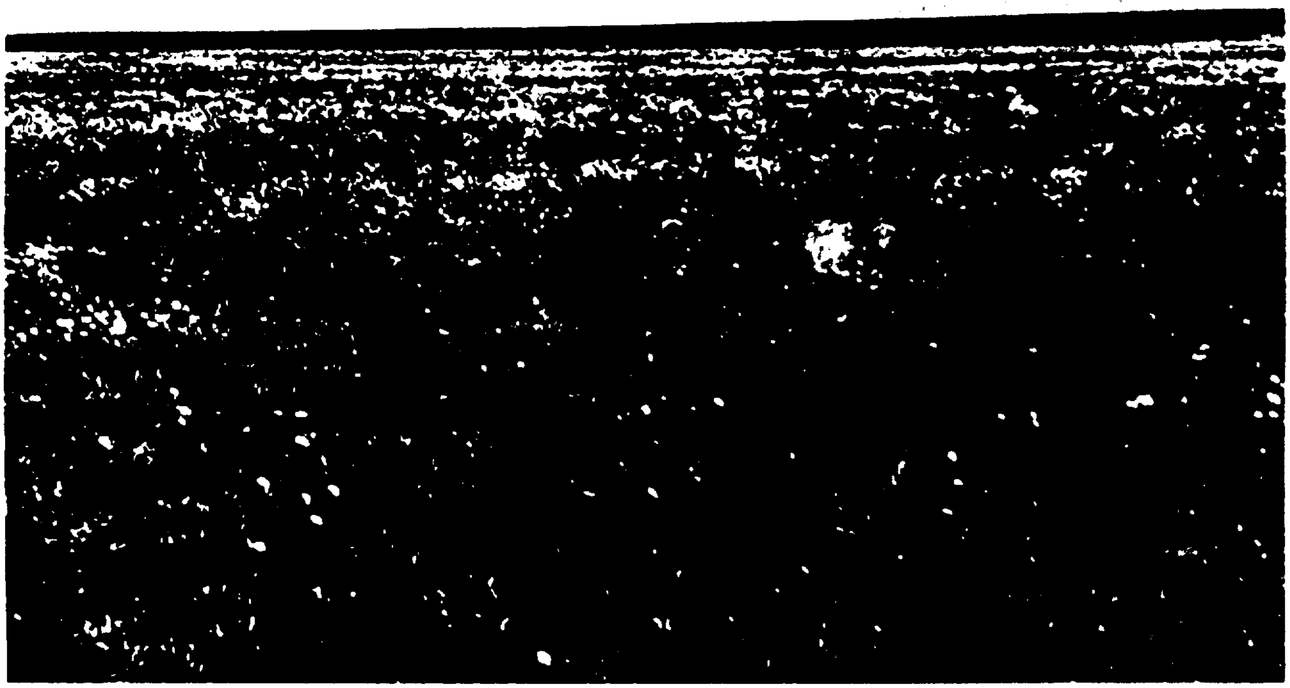

FIGURE 5

Tundra Adjacent to the West Channel of the Colville River

The predominant plant here is "cotton-grass" (Eriophorum).
Note absence of trees. Tundra mosquitoes will bite
on the leeward side in winds
up to 12 miles per hour.

FIGURE 6

Small Semipermanent Pool in Tundra Which Holds Water Throughout Most of the Summer.

Such pools usually contain large numbers of larvae in early July During August, 1962, when this picture was taken, pupal cases averaged 250 per dip. We had arrived about one week after the adults had emerged and thereby paid the penalty to the adult mosquitoes.

FIGURE 7

Polygons Characteristic of Parts of the Tundra on the Arctic Slope

Permafrost lies only a few inches below the surface of the ground in the summer. As the snow melts in the spring, the frozen ground retains the water at the surface, thereby providing breeding places for the "tundra" mosquitoes. The mosquito season north of the Brooks Range lasts approximately one month, but while it lasts, it is probably the most intense one in the world. Photo by F. White.

The aforementioned list of mammals in the Eskimoan Biotic Province includes: Sorex arcticus (arctic shrew), Sorex cinereus (masked shrew), Lepus othus (Alaskan hare), Marmota caligata (hoary marmot), Spermophilus undulatus (arctic ground squirrel), Clethrionomys rutilus (red-backed vole), Dicrostonyx groenlandicus (collared lemming), Lemmus trimucronatus (brown lemming), Microtus miurus (singing vole), Microtus oeconomus (Arctic vole), Alopex lagopus (arctic fox), Canis lupus (gray wolf), Vulpes fulva (red fox), Ursus horribilis (grizzly bear), Gulo luscus (wolverine), Mustela erminea (ermine), Mustela rixosa (least weasel), Alces alces (moose), Rangifer tarandus (caribou), Ovis dalli (Dall's sheep). The caribou probably is the most important animal in furnishing a blood meal for the "tundra" mosquitoes.

Hudsonian Biotic Province:

This area is limited in the north at the tree line (spruce forests) on the south slope of the Brooks Range, in the south by the north slope of the Coast Range, and by altitude on various mountain systems in between. To most ecologists, this area is included in the "taiga." However, the taiga also includes the Canadian Biotic Province, which does not occur in Alaska. Therefore, the application of the term in this discussion is more restricted than usual. The Hudsonian is essentially transcontinental, stretching from Newfoundland to western Alaska, but is prevented from reaching the coastline by a narrow strip of the tundra (Eskimoan Biotic Province), as illustrated in Figures 2 and 3. It reaches the Pacific Ocean only in a narrow strip at Cook Inlet.

On the south slope of the Brooks Range, the Hudsonian has many finger-like processes extending up into the low, protected valleys; likewise, it is penetrated by tundra along the mountain ridges at the higher elevations, as can be observed in Figure 3.

This is the "Zone of Discontinuous Permafrost," and the climate is characterized as a cold continental one (i.e., short, warm summers and long, cold winters.) A large part of our study was conducted in the Tanana Valley, which is typified by data obtained in the Fairbanks environs, with a mean annual temperature of 26.1° F and extremes of 99° F and -66° F. The mean annual precipitation is 11.7 inches, 60% of which falls during the period from May to September as rain. The mean annual snowfall is 67 inches. The Tanana Valley has been subjected to considerable ecological disturbance. At first, this was due to gold mining operations, and this has been followed by attempts at homesteading for agricultural purposes and the production of rough lumber used in construction and housing needs. Military bases within the area have also changed the landscape. It is difficult to find virgin stands of timber because much of it has been burned over since the arrival of the prospectors about the turn of the century. However, some stands of white spruce that are 2 1/2 feet in diameter can be found along the margins of streams.

Dr. Allan Mick, formerly an agronomist at the University of Alaska Experimental Farm, has informed me that the temperature of the soil varies considerably once the original cover is disturbed. For example, many of the plots in the experimental farm have shown a warming of 20° F since the ground was first cleared. Such a temperature change should have a remarkable effect upon the mosquito fauna, and it is believed that we have information to substantiate this point. The expansion of the highway system in Alaska is aiding the distribution of certain mosquitoes and mammals.

As more land is cleared within the Tanana Valley, a shift in the abundance of certain species of mosquitoes will no doubt occur. With the warming of the soil brought about by the clearing, such mosquitoes as Aedes excrucians and other banded-legged Aedes should increase in numbers and occur earlier in the year. Aedes pionips undoubtedly will increase in numbers. However, proper drainage practices carried out with the clearing operations could cause a lessening of the populations.

The vegetation on undisturbed ground now consists of white spruce, paper birch, willow, balsam, poplar and some larch, growing in pure and mixed stands along rivers, sloughs, lakes and minor drainage courses. Birch, aspen and white spruce grow on bedrock slopes, hills and burned-over areas on glacial outwash plains. Dense, black spruce forest covers undisturbed areas on outwash plains. Upland valleys are covered by muskeg ("tundra" of some authors) consisting of sedges, grasses, dwarf birch, small heaths, or stands of stunted black spruce, willows and alder. As one becomes familiar with the area, one notes that stands of tall willows and isolated pure stands of balsam poplar on flood plains indicate the presence of unfrozen ground. Areas overgrown by black spruce are likely to be underlain by permafrost at a shallow depth. Throughout much of Alaska, the forests are limited to the slopes at lower altitudes and to the better drained parts of the valley floor.

Characteristic plants are: Picea mariana (black spruce), Picea glauca (white spruce), Betula papyrifera (paper birch), Larix laricina (tamarack or larch), Populus balsamifera (balsam poplar), Populus tremuloides (aspen), Salix spp. (willows), Alnus incana (alders), Betula glandulosa (dwarf birch), Vaccinium (blueberries), Ledum groenlandicum (Labrador tea), Equisetum (horsetail), Eriophorium vaginatum ("niggerheads"), and Eriophorium scheuchxeri (cotton grass). Low-bush cranberry frequently is abundant on well-drained slopes, particularly in mixed birch-spruce forests.

The animals encountered in the Hudsonian Biotic Province are not all characteristic of the taiga. Indeed, few mammals are confined solely to any one Biotic Province, although when occurring in more than one, they are not of equal abundance in both areas. For example, this is particularly true of the red-backed vole (Clethrionomys rutilus) and the wolverine (Gulo luscus), the former typically a taiga animal but with a broad distribution in the tundra.

The latter is a tundra representative which occurs in lesser numbers in the taiga. Again I have listed certain animals, for example the arctic ground squirrel (Spermophilus undulatus osgoodi and Spermophilus undulatus plesius) as well as the pika (Ochotona collaris) and the marmot (Marmota caligata), which are usually associated with the upland areas, the last two being largely confined to talus slopes. Spermophilus u. osgoodi is particularly difficult to classify from this standpoint because it will occur in the lowlands, for example, along the Steese Highway from Central to Circle. In the Circle Hot Springs area it has been observed in the aspen-spruce association. However, by far the greater preponderance of the population in the lowlands is in the cleared areas, thereby conforming in part to the major portion of the animal's range above timberline.

Thus, the following list of mammals is provisional, and I do not mean to imply that they are strictly taiga representatives: Sorex arcticus (arctic shrew), Sorex cinereus (masked shrew), Microsorex hoyi (pigmy shrew), Lepus americanus (varying hare), Ochotona collaris (collared pika), Glaucomys sabrinus (flying squirrel), Marmota caligata (hoary marmot), Marmota monax (woodchuck), Spermophilus undulatus osgoodi (arctic ground squirrel), Spermophilus undulatus plesius (arctic ground squirrel), Tamiasciurus hudsonicus (red squirrel), Castor canadensis (beaver), Clethrionomys rutilus (red-backed vole), Lemmus trimucronatus (brown lemming), Microtus oeconomus (Arctic vole), Microtus pennsylvanicus (meadow vole), Ondatra zibethicus (muskrat), Zapus hudsonius (jumping mouse), Erethizon dorsatum (porcupine), Canis lupus (gray wolf), Vulpes fulva (red fox), Lynx canadensis (lynx), Ursus horribilis (grizzly bear), Ursus americanus (black bear), Gulo luscus (wolverine), Martes americana (marten), Mustela erminea (ermine), Mustela rixosa (least weasel), Mustela vison (mink), Alces alces (moose), Rangifer tarandus (caribou).

In undisturbed areas, I think the larger mammals such as moose, caribou, varying hare (when abundant) and the arctic ground squirrel provide the major source of blood meals in the taiga.

The Hudsonian mosquitoes are: Aedes canadensis (Theobald, 1901); Aedes cataphylla Dyar, 1916; Aedes cinereus Meigen, 1818; Aedes communis (DeGeer, 1776); Aedes decticus Howard, Dyar, and Knab, 1917; Aedes diantaeus Howard, Dyar, and Knab, 1917; Aedes excrucians (Walker, 1856); Aedes fitchii (Felt and Young, 1904); Aedes hexodontus Dyar, 1916; Aedes impiger (Walker, 1848); Aedes implicatus Vockeroth, 1954; Aedes intrudens Dyar, 1919; Aedes nigripes (Zetterstedt, 1838); Aedes pionips Dyar, 1919; Aedes pullatus (Coquillett, 1904); Aedes punctor (Kirby, 1837); Aedes riparius Dyar and Knab, 1907; Aedes stimulans (Walker, 1848); Anopheles earlei Vargas, 1943; Culex territans Walker, 1856; Culiseta alaskaensis (Ludlow, 1906); Culiseta impatiens (Walker, 1848); and Culiseta morsitans (Theobald, 1901). Most important of these mosquitoes are Aedes intrudens, Aedes punctor, Aedes excrucians and Culiseta alaskaensis.

Sitkan Province

This occupies most of what is known as the "panhandle" or southeastern Alaska. The climate is characterized as being a cool but equable one. For instance, January is usually the coldest month, and it is seldom that the temperature is lower than 32° F; July is the hottest month, and the average temperature is 57.5° F. The maximum recorded temperature of 96° F and a minimum of -8° F have been recorded at Ketchikan. The temperature is surprisingly uniform for such a long, relatively north-south strip of land. For example, during January the average temperature at Juneau is 27° F, while the hottest month, July, has an average temperature of 56.6° F, with a range of from -15° to 89° F The precipitation, however, is more variable. The average annual precipitation at Ketchikan is 150.89 inches, with May, June and July being the driest months. Juneau has an average annual precipitation of 83.25 inches, with a similar dry spell. Average snowfall approximates 100 inches annually.

This area was extensively glaciated during the Pleistocene, and many large glaciers still occur. Timberline ranges between 1,000 and 2,000 feet as a general rule, but may vary from 500 to 3,000 feet. The Sitkan Province is extremely mountainous; much of it is broken by the sea into chains of mountainous islands, which in turn are separated by tide-swept channels. The boundaries for the Sitkan Biotic Province are somewhat arbitrary; however, it is generally limited to the heavy coastal coniferous forests which extend from near Kodiak Island southeastward to the southern tip of Alaska. In an eastward direction, the boundary between the Sitkan and the Hudsonian Province is placed along the top of the Coast Range. (In early studies this range included what are now known as St. Elias Mountains and the Coast Mountains.)

The most important or characteristic trees in the heavily forested areas at the lower elevations are: Chamaecyparis nootkatensis (Alaskan cedar), Tsuga heterophylla (western hemlock), Tsuga mertensiana (mountain hemlock), Picea sitchensis (Sitka spruce), Salix spp. (willow) and Populus tricocarpa (black cottonwood).

Some of the characteristic mammals are: Sorex obscurus (dusky shrew), Sorex palustris (water shrew), Myotis lucifugus lucifugus (little brown myotis), Spermophilus undulatus (arctic ground squirrel), Tamiasciurus hudsonicus (red squirrel), Peromyscus maniculatus (deer mouse), Phenacomys intermedius (mountain phenacomys), Microtus longicaudus (long-tailed vole), Microtus oeconomus macfarlani (tundra vole), Erethizon dorsatum (porcupine), Ursus horribilis (Alaskan brown bear), Mustela vison (mink), Mustela erminea (ermine), Alces alces (moose), and Dama hemionus (black-tailed deer).

From what is known of the siphonapterous fauna of this region, the species are more representative of the Pacific Northwest than they are of

the Hudsonian or Eskimoan Biotic Provinces. This seems truly amazing when it is observed that the mosquito fauna is representative of the two Northern Biotic Provinces. At first glance it would seem that the mosquitoes would have a better chance to invade the southeastern part of Alaska from the south (Pacific Northwest) than the fleas. Perhaps the most valid conclusion that can be drawn from the above evidence is that not enough data have been accumulated for either the fleas or mosquitoes!

Any attempt to explain the biogeography of southeastern Alaska should take into account the recent recession of the glaciers there and the comparative isolation still caused by sea, ice and mountain barriers. However, radio carbon dating, (17), shows no such great age difference from the north temperate United States as one might expect. For example, much of Maine was still covered by the Wisconsin Glacier for about 1,000 years after the bog on upper Montana Creek near Juneau melted and began accumulating peat about 5,000 years ago (62). However, this geologically short period, operating in conjunction with the barriers mentioned above and the lengthy (although mild) winters in southeastern Alaska, has combined to keep many organisms out of the area up to the present time. Some mosquitoes, for example Culiseta alaskaensis and Aedes excrucians, have been able to penetrate into the region only as far as Haines and Wrangell, where major rivers have provided an avenue from the interior. However, along the coast and perhaps by island-jumping, two mosquitoes, Culiseta incidens and particeps, have penetrated northward. These last two mosquitoes are otherwise typical of the West Coast temperate forms in the lower 48 states. A further factor is the cool summer climate of southeastern Alaska. The region is relegated to the temperate zone in recognition of its mild winters, despite its cool summer climate. In comparing the list of the mosquitoes of this region with that of the Hudsonian, it is interesting to note that the genus Anopheles is not represented in the so-called "temperate" region of Alaska.

According to Frohne (35), there are no mosquitoes in this area which produce more than a single annual brood. The mosquito biting season is long, over 5 months. The absence of Culex and Anopheles suggests that the southeastern mosquito fauna is of the Arctic type rather than a temperate one, as one ordinarily would expect.

The mosquito fauna of the Sitkan Biotic Province is thought to consist of approximately 12 species. Except for the report by Frohne (36), only meager information is available. A more thorough study of the fauna is needed in this region and would undoubtedly increase the number of species known. The species reported thus far are: Aedes aboriginis Dyar; Aedes cinereus Meigen; Aedes communis (DeGeer); Aedes excrucians (Walker); Aedes pionips Dyar; Aedes pullatus (Coquillett); Aedes punctor (Kirby); Culiseta alaskaensis (Ludlow); Culiseta impatiens (Walker); Culiseta incidens (Thomson); Culiseta morsitans (Theobald); Culiseta particeps (Adams).

According to Jenkins (79) the mosquitoes of the Boreal region consist of 36 species. The distribution of these mosquitoes is summarized in Table I.

TABLE I

DISTRIBUTION OF THE BOREAL MOSQUITO FAUNA
(Total - 36 Species)

Region	Number of Species
North America	30
Eurasia	22
Holarctic	20

From the information presented here, it would seem that North America has a larger fauna, but this is not necessarily the case. The difference in the number of species is more than likely due to a difference in taxonomic approach in the two areas. For example, many Eurasian workers have not concurred with the splitting of the *Aedes communis* complex to the extent that has been done by North American workers. Some difference is also bound to have occurred because of the emphasis placed on the northern mosquitoes in our own fauna since World War II.

III

LIFE CYCLE

Alaskan mosquitoes can be placed in two groups, depending upon their life cycles. Wesenberg-Lund (144) established four types of life cycles for the mosquitoes of the world; these four have withstood the test of time, except for one modification to be mentioned below. The first type, the *Aedes cinereus* type of life cycle, is typified by all *Alaskan Aedes*, in which hibernation or overwintering takes place solely in the egg stage. The eggs, larvae and sometimes pupae, are cold-tolerant forms. This is the only type of life cycle known for those mosquitoes which inhabit the Arctic Slope. A fifth type of life cycle was proposed by Frohne (34, 35) in which hibernation is accomplished in the adult stage. This differs from the fourth type described by Wesenberg-Lund (144) and by Bates (4) because although the females are inseminated before hibernation, they do not seek a blood meal at this time. Recent information indicates this behavior may be true for many mosquitoes of the temperate region. Frohne further believed that the mosquitoes with this type of life cycle were again single-brooded. To this latter type of life cycle belong all of the mosquitoes that are placed in the genera *Anopheles*, *Culex* and *Culiseta*. These constitute a very small proportion of the total mosquito fauna in Alaska.

Much has been said about the cold-hardiness of Alaskan mosquitoes without the writers really understanding the actual ecology. Pruitt (112) reported on temperatures beneath the snow in Alaska, and it is extremely significant that once 19 cm of snow have accumulated on the ground, the temperature next to the earth does not get lower than 16° F These studies were conducted in the taiga, and it is thought that such a temperature would likely be found throughout most of the alpine regions of the Rocky Mountains. Most individuals have had a common concept that the mosquitoes and their eggs were surviving the winter exposed to the extremely low temperatures that are known above the snow cover. From information now available (that will be reported in more detail), we now know that the adults of Culiseta alaskaensis and those of Culex territans hibernate below the snow in clumps of Calamagrostis grass very close to the ground. We have never found that these adult mosquitoes are able to withstand temperatures below 0° F in the laboratory for any prolonged period of time.

IV

BITING STUDIES

Among the many facets of this investigation, none was so germane to all others as the study of the biting habits of boreal mosquitoes. Prior to this investigation, virtually nothing was known about their disease-vectoring potential, but for any insect to be a vector of an agent pathogenic to man, usually it must obtain at least two blood meals, the second one from man. Regardless of what diseases these northern mosquitoes might carry, their feeding habits are such that no other group of animals serves as such a strong deterrent force to man's living in this region of the world.

Apparently, the mosquito problem in Alaska has changed very little since it was first recorded by early travelers and explorers. I do not mean to imply that the mosquito season is the same each year, because it does vary with the abundance of the total population and with the dominance of a given species in any one year. There are times in Alaska when the mosquito population is not any greater than it is in any part of the temperate region; however, in some years the mosquitoes have occurred in intolerable numbers and thus have accounted for some graphic writings by early explorers. The following brief accounts by three early scientists are given here because they provide something of an insight as to what the situation was in Alaska and other northern regions before the invasion by European populations.

In 1880 Petrof investigated Alaskan resources and later published his findings. He found the mosquitoes to be an extremely severe annoyance in the Kuskokwim Valley, as indicated by the following brief excerpt from his writings:

"There is another feature in this country which, though insignificant on paper, is to the traveler the most terrible and poignant infection he can be called upon to bear in a new land. I refer to the clouds of blood-thirsty mosquitoes, accompanied by a vendictive ally in the shape of a small poisonous black fly, under the stress of whose persecution the strongest man with the firmest will must either feel depressed or succumb to low fever... The traveler who exposes his bare eyes or face loses his natural appearance; his eye lids swell up and close, and his face becomes one mass of lumps anf fiery pimples. Mosquitoes torture the Indian dogs to death, especially if one of these animals, by mange or otherwise, loses an inconsiderable portion of its thick hairy covering, and even drive the bear and deer into the water." (107).

Abercrombie (1) camped several days in the area that is now known as Copper Center, and he reports on the mosquito populations for that time of the year (June 9-13) as follows:

"The long expected pests, the mosquitoes, were out in full force, during this day at this camp, and the men were compelled to wear veils day and night with gloves to protect the hands. The ferocity of these mosquitoes are regarded as something remarkable. The species found here is not the large, singing sort seen in the States, but a small, silent, business-like insect, sharp of bill, who touches a tender spot in a surprisingly short time after biting. After making their appearance, they never left the expedition for a day." (1).

Seton (125) gives an account of his experiences in the Barren Grounds of Canada. He reports:

"Each day they got worse; soon it became clear that mere adjectives could not convey any idea of their terrors. I therefore devised a mosquito gauge. I held up a bare hand for five seconds by the watch, and counted the number of borers on the back; there were five to ten. Each day added to the number and when we got to the buffalo country, there were fifteen to twenty-five on the one side of the hand and elsewhere in proportion. On the Nyarling, in early July, the number was increased, being now 20 to 40. On Great Slave Lake, later that month, there were 50 to 60. But when we reached the Barren Grounds, the land of open breezy plains and cold water lakes, the pests were so bad that the hand held up for five seconds often showed from 100 to 125 long-billed mosquitoes boring away into the flesh. It was possible to number them only by killing them and counting the corpses. What wonder that all men should avoid the open plains, that are the kingdom of such a scourge." (125).

The above account by Seton is the only one known to me in which the numbers of mosquitoes were actually counted. If the mosquitoes in Seton's account were to continue to bite at the same rate, they would total approximately 18,000 mosquitoes for a 15-minute period! This is the interval that we used to obtain our information regarding the biting habits of Alaskan mosquitoes, and we never approached nearly as high a figure. What I considered intolerable numbers of mosquitoes were encountered at the mouth of the Anaktuvuk River in July of 1962. At this time, we secured 1,253 mosquitoes.

Twenty-four Hour Biting Studies

These particular studies were done to obtain information about the effect of seasonal change on the species complex encountered in the taiga, and to determine if and to what extent climatic conditions influence the biting rate or feeding habits of these insects. White laboratory rabbits and human volunteers were used as bait. The ventral surface of the rabbit was shaved, and an area of 54 square inches (9 by 6 inches) was outlined with a marking pencil. The rabbit was then immobilized on a board, as illustrated in Figure 8, and completely covered with a heavy burlap material for a period of 20 minutes to prevent the mosquitoes from feeding upon it. An identical area on the forearm of a human volunteer was utilized.

The 20-minute period was necessary to obtain phenological data, such as temperature, relative humidity, light and wind velocity, prior to the feeding. In addition, it allowed the mosquitoes to settle to a more or less normal activity after being disturbed and attracted to us in abnormal numbers as we walked through the woods to the study site. Biting samples were conducted for 15 minutes, and all the biting insects were collected with an aspirator and placed in killing tubes. Only those insects which had inserted their proboscises and showed some distention of their abdomens were taken. Insofar as I know, this is the only time that such a method has been utilized, but our preliminary studies had indicated that the "landing rate" method used by earlier workers was not of particularly significant value, since many of the mosquitoes would land on one's clothing and fly away without attempting to feed. We noted this to a disturbing degree even upon the exposed forearm of man and on the shaved ventral surface of the rabbit. Such biting studies were conducted weekly at 2-hour intervals over a 24-hour period. The studies were conducted 34 to 36 inches above the ground, because preliminary experiments had indicated this was close to the optimum elevation for subarctic mosquitoes.

Coveralls of the same material and color were provided for all personnel involved in this study. Sets of gloves and headnets were set aside especially for this use, in order to have as uniform a condition as possible. Preliminary studies had indicated that dark colors, such as red or green, would attract a good many more mosquitoes to the same person than when he was dressed in light colors.

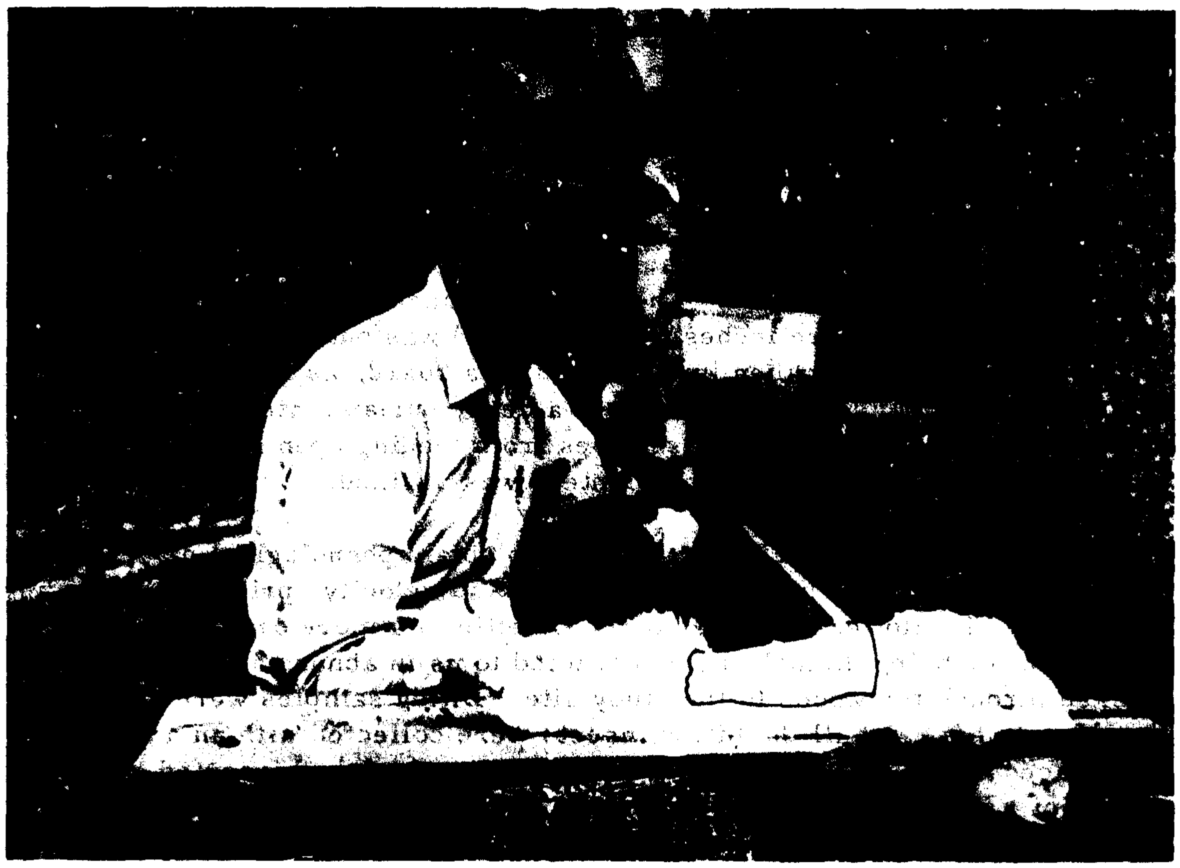

FIGURE 8

Collecting Mosquitoes During a 15-Minute Biting Period

The black line outlines an area of 54 square inches, equivalent to an average-sized human forearm. Up to 194 mosquitoes were taken, whereas the maximum number collected from one of us (forearm) was 350 in a similar period of time.

The principal area used for the biting studies was a wooded site adjacent to Peede Road, approximately 7-1/2 miles southeast of Fort Wainwright. This study area was granted to us by Mrs. A. H. Nordale, and hereafter in this discussion it will be referred to as the Nordale study site. The forest cover was perhaps as close to a virgin stand of white spruce as one could find within a radius of 50 miles of Fairbanks. There were a few paper birches and cottonwood trees intermingled with the spruce; the forest floor was covered with a deep layer of various species of mosses. This site was picked because it was relatively undisturbed ecologically; no trees had been removed from the area for about 50 years. At least, this was true at the beginning of the study; some trees were taken out during the spring of 1962, but this operation was stopped as soon as it was known that we wanted to continue our studies in 1962. Another factor influencing our selection of the site was that it would not be influenced too rapidly by minor climatic changes, and studies in the past had indicated that through the years it had as heavy a population of mosquitoes as could be found anywhere in the Fairbanks vicinity. Generally, in the heavy spruce forest the mosquito season seems to last a week or so longer than in the open area or in the stands of secondary growth.

Table II summarizes the data collected from the biting studies utilizing rabbit abdomens and forearms of human volunteers. There were 9,466 specimens obtained during the two seasons, and as indicated in Table II, there was a higher average biting rate per period from the human host than from the rabbit. In fact, the average was almost double.

TABLE II

AVERAGE NUMBER OF MOSQUITOES BITING
DURING A 15-MINUTE PERIOD

Host	Average per Biting Period 1960	1961
Forearm (Man)	54.17	69.23
Rabbit	24.11	32.12

The maximum number from one feeding period was 350 from the man and 194 from the rabbit. It must be kept in mind that while the mosquitoes were only allowed to feed on areas of the same size in both rabbits and men, the mass of the human body exuding carbon dioxide and heat was far larger than the total mass of the rabbit. This was perhaps partly responsible for the difference in the data obtained. A breakdown by species did not reveal any significant shift between these two hosts. In other words, the same species were dominant upon both. In order of abundance were <u>Aedes</u> <u>excrucians</u>,

Aedes punctor, Aedes intrudens and Aedes pionips. Inasmuch as the studies did not start until shortly after the first of June during these two years, the peak for Culiseta alaskaensis had already passed and only an occational specimen of this mosquito was encountered. Several other species were encountered more or less routinely, but they did not make up anywhere nearly so great a proportion of the biting records as either of the four species of Aedes mentioned above. It may be well to note, however, that Aedes stimulans was at times reasonably abundant, as was Aedes communis.

Quite by accident during the summer of 1959, while carrying out some investigations at the Wilbur Creek study site, it was observed that as one progressed upward in elevation from the ground, the biting records decreased considerably above 18 feet. This was checked occasionally during the summers of 1960 and 1961, and consistently the same results were obtained. With this concept in mind, and in view of much literature dealing with inversion factors of temperature and mosquito behavior in recent years, it was decided to erect a tower that would be high enough to reach the average height of the trees in a forested area. Figure 9 shows the tower that was constructed to study the vertical distribution of mosquitoes. Insofar as I know, this was the first serious attempt to obtain biting records by this method in the subarctic. Figure 10 shows one of the bait boxes, as well as a box which housed a hygrothermograph.

The tower utilized three white spruce that were standing upright from each other in a triangular position. The platforms were placed at 6-foot intervals and were triangular in outline. The highest platform was 42 feet above the ground. A fourth tree had grown adjacent to one of the trees and was close enough to be used for the construction of a ladder. To give some additional steadiness to the tower, guide wires were run down from near the top of each tree. The tops of the trees were chopped off.

Host studies revolved around standard white laboratory rabbits, varying hares and domestic chickens. On rare occasions native gallinaceous birds (willow ptarmigan and rough grouse) were utilized. Each type of host was placed in the bait box at each level for a 24-hour period; at the end of this time the mosquitoes were removed with an aspirator and the host was taken out of the bait box. A period of 12 hours was then allowed to elapse before a different host was placed in the box, and one 24-hour period was tested when the boxes were empty, to serve as a control. Figure 11 shows one of the bait boxes in considerable detail. The wooden door would slide back for insertion of the host animal; the netting prevented the mosquitoes from gaining entrance during this operation and prevented them from escaping after being attracted into the box by the host. The varying hare (Figure 12) because of its excitability, had to be restrained within a small, hardware cloth cage which permitted movement but prevented it from damaging the screen "V"-shaped baffles at each end of the box. These baffles allowed the

FIGURE 9

Tower Constructed in Nordale Woods to Study the Vertical Distribution of Mosquitoes in a Forested Area

Weather boxes with hygrothermographs and "bait boxes" used in studying host attraction of subarctic mosquitoes were placed on the ground and at each level. Highest level was 42 feet above the ground.

FIGURE 10

Weather Box (1) and Bait Box (2) at Ground Level of the Tower Shown in Figure 9

The weather box housed a hygrothermograph. The bait boxes were used to house a variety of animals in an attempt to gather data on host preferences.

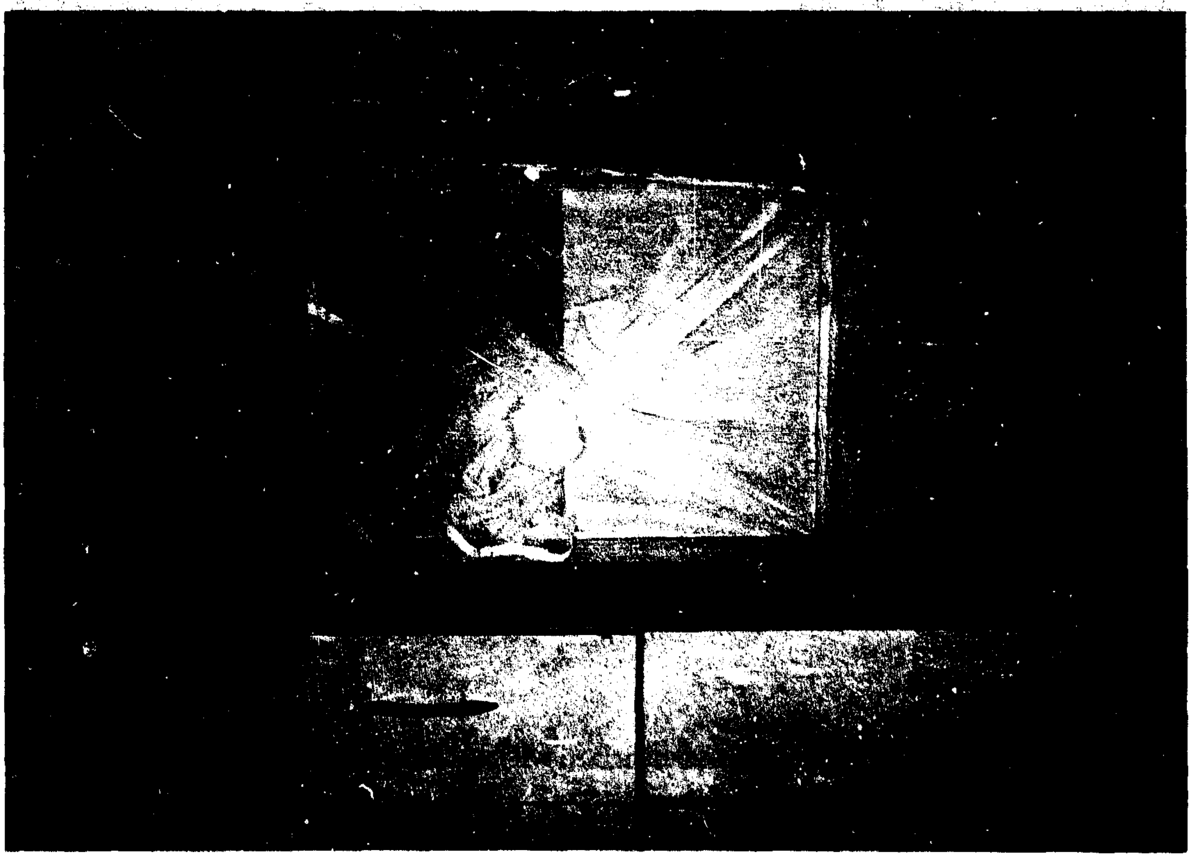

FIGURE 11

Bait Box in Detail

Ingress baffles located at ends of box permit entrance of the mosquitoes.

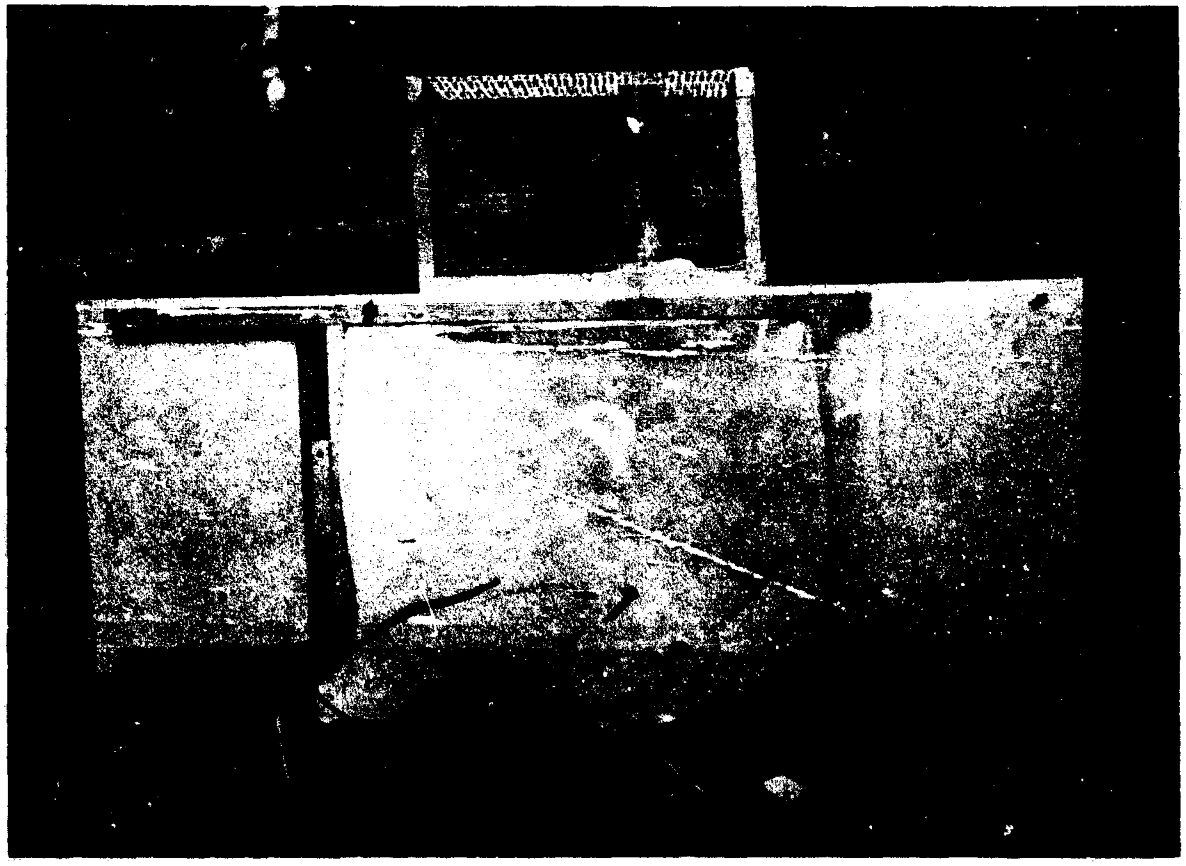

FIGURE 12

Bait Box Showing the Enclosure Used to Contain a Varying Hare

The hare proved to be the most favorable host utilized in this study, not only in total numbers, but also in the percent of engorged mosquitoes.

mosquitoes to enter but not to escape. It was found that the beaks of chickens had to be clipped as illustrated in Figure 13 to prevent them from pecking and/or eating the mosquitoes that were engorged. Preliminary studies indicated that the outside color of the bait box made little if any difference in the capture rate; therefore, all were painted white to make them easier to see.

Table III represents the mosquitoes taken during the summer of 1962 from the various animals that were routinely used. A significant point is the drop in the total number of mosquitoes taken beyond the 18-foot level. To check this further, we stationed human volunteers on each platform for 1-hour intervals several times throughout the course of the study and obtained essentially the same results. During the height of the mosquito season, one never needed to worry about the mosquitoes on the highest three platforms; it was perfectly enjoyable to be there without any protective measures and not receive more than an occasional bite. Within the taiga, I feel this is of practical significance, since as a person lost and without protection from the mosquitoes at ground level could secure reasonable freedom from them if he were able to climb high enough in a tree. There are times when this could possibly mean the difference between survival and death.

In an effort to check the mosquito populations adjacent to Nordale Woods, professional insect nets were utilized in a sweeping fashion describing an arch of 180^{o} in front of the investigator and in the vegetation. This was done in an effort to determine whether the species we were getting in the biting studies were indeed a true cross section of the mosquito population in the area. Cursory classification of mosquitoes has indicated that our biting specimens were indeed a valid cross section. Of 46,123 mosquitoes captured this way, six were encountered that had had a previous blood meal. Figure 14 graphically portrays part of the results presented in Table II. It is evident from this figure that the varying hare was more attractive to the mosquitoes than either of the other animals used. From this figure, one would be led to believe that the domestic chicken was reasonably attractive to the subarctic mosquitoes; however, an examination of the percentage of the mosquitoes that were engorged in the bait boxes housing the chickens (Figure 15) shed quite a different light on the matter. Only 18.2% were engorged, compared to 70% for the laboratory rabbit and 92% for the varying hare. This would be in agreement with the studies carried out by Downe (26), who concluded that the chickens were quite unattractive to the mosquitoes.

The above information is particularly interesting when one reviews the records of Natvig (103), who recorded various species of mosquitoes attacking nestling birds in Norway. According to Natvig, Aedes punctor was observed feeding on a sparrow hawk, Aedes communis on grouse, and Aedes excrucians and Aedes intrudens on the golden eagle. Natvig also reported the following nestling birds were attacked by unidentified species of mosquitoes: the rough-legged hawk, rook, crow, gull, lapwing and kestrel. Thienemann (133) recorded Aedes punctor and Aedes communis feeding on

FIGURE 13

Domestic Chicken Used as One of the Hosts in the Biting Studies

The bill was clipped to prevent the chickens from eating the mosquitoes within the box. From the results of this study, and observations in the field with passerine birds, it is doubted that birds play a significant role as a source of blood for subarctic mosquitoes.

TABLE III

NUMBER OF MOSQUITOES ATTRACTED TO THE VARIOUS HOSTS AT DIFFERENT LEVELS ON THE "MOSQUITO TOWER"

	Distance from Ground	Laboratory Rabbit	Domestic Chicken	Varying Hare	Control	Total for Level
Ground	6"	811	733	1,250	156	2,950
p. 1	6'	823	477	960	150	2,410
p. 2	12'	580	481	853	95	2,009
p. 3	18'	420	319	592	60	1,391
p. 4	24'	264	240	370	7	881
p. 5	30'	276	81	223	10	590
p. 6	36'	90	63	180	5	338
p. 7	42'	63	41	93	6	203
TOTALS		3,327	2,435	4,521	489	10,772

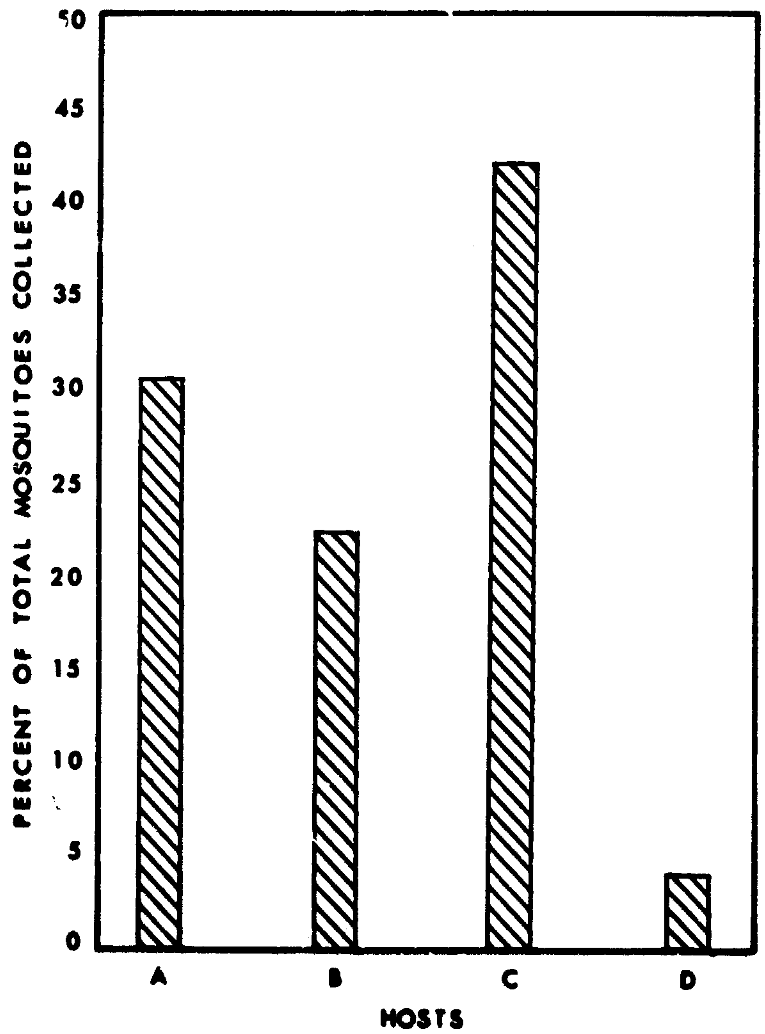

FIGURE 14

Percentage of Mosquitoes Attracted to Each Host in th~ Study of Vertical Distribution of the Mosquito

Data for this figure were taken from the preceeding table. A. white rabbit, B. domestic chicken, C. varying hare, D. control (empty bait box).

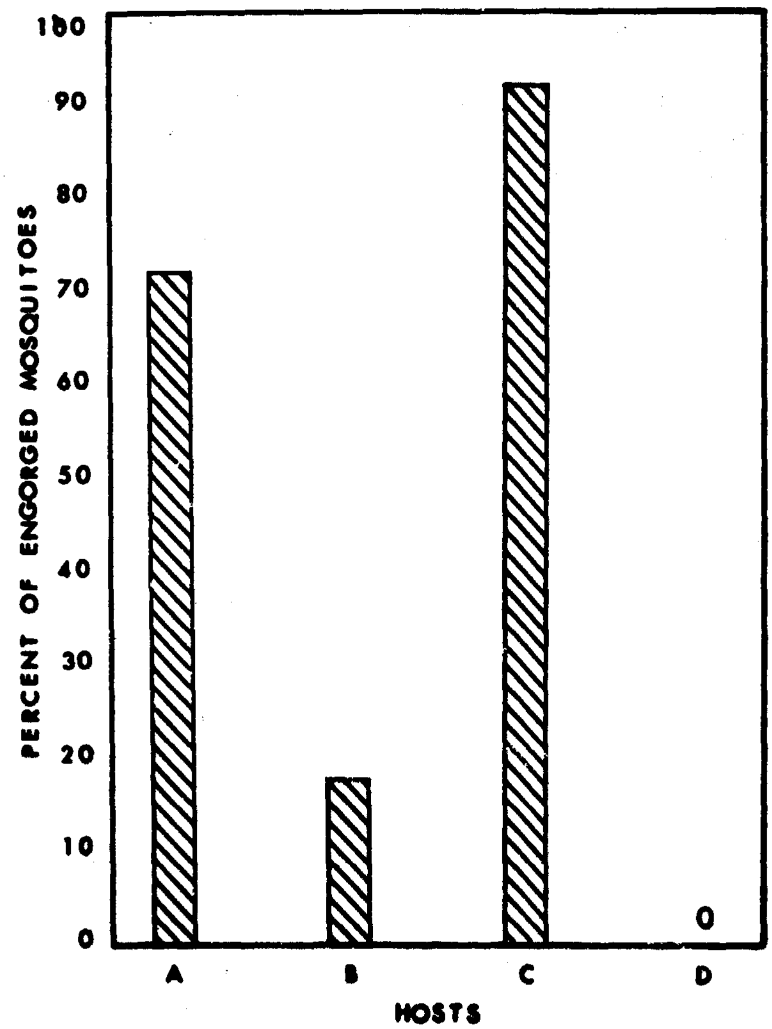

FIGURE 15

Percentage of Captured Mosquitoes that were Found Engorged in the Bait Boxes with the Various Hosts

Although the domestic chicken attracted a reasonable number of mosquitoes into the box, very few sought a blood meal. A. white rabbit, B. domestic chicken, C. varying hare, D. control (empty bait box).

voles and lemmings, and he indicated that these animals probably constituted the principal source of blood meal for the mosquitoes in the Scandinavian Arctic. Longstaff (95a) has reported Aedes nigripes feeding on the redpoll and possibly on the arctic hare in Greenland.

The observations of the above-mentioned authors in regards to the avian hosts are in distinct contrast to what I have noted during the several summers that I have been in Alaska. Figure 16 shows a mealy redpoll (Acanthis flammea flammea) sitting on a nest which was located approximately 2 1/2 feet from the ground. During several hours of watching this bird through the nesting period, no mosquitoes were ever observed to feed upon her. Eventually one could stand as close as 12 inches from the nest and have innumerable mosquitoes attempting to attain a blood meal from oneself; yet none were noticed seeking a meal from the redpoll. After the eggs had hatched, one could stand immediately adjacent to the nest and observe the same nonbiting phenomenon with the nestlings. I have noticed the same reluctance of mosquitoes to feed on young flickers whose bodies were essentially nude; they could be placed in the open, and apparently the mosquitoes paid little or no attention to them. I have made this same observation with white-crowned sparrows, yellow warblers, olive-backed thrushes, and rusty blackbirds. I realize that my studies are not exhaustive enough to say irrevocably that the birds are not important, but I have a strong feeling that they do not contribute significantly to the feeding requirements of subarctic mosquitoes.

With regard to Thienemann's report (133) regarding voles and lemmings, I also feel that this is an untenable concept. The voles and lemmings generally are most active during the cooler part of the 24-hour cycle, and frequently this temperature is below the level at which the mosquitoes do most of their biting. Certainly, the voles are moving through the vegetation so rapidly that the mosquito has little or no chance to stay on them long enough to become engorged. Most likely, at least in my observations, the mosquitoes would be brushed off as the rodent passed through the vegetation. On the other hand, I have observed the arctic ground squirrel (shown in Figure 17) and know that on windless days in the tundra regions (Arctic Slope) the mosquitoes can make life literally as unpleasant for this rodent as they do for the human observer. The same observations have been made in the upland tundra above the Hudsonian Biotic Province. If a rodent is important, then probably this one animal constitutes a reasonably good source of food.

Among the lagomorphs, the varying hare in the taiga region feeds a large number of mosquitoes. When this hare is in abundance, the subarctic mosquitoes have an ample opportunity to obtain a blood meal. I have watched these mosquitoes feed on the hare at relatively close range, and with the aid of field glasses, have been able to count as many as 25 mosquitoes in various stages of engorgement on one ear. Frequently, in what would ordinarily be the crepuscular period at lower latitudes, varying hares will sit along the side of the road or in open areas for variable lengths of time with swarms of

FIGURE 16

Mealy Redpoll (Acanthis flammea flammea)

In the subarctic, one can usually approach a nesting bird closely. I have never seen mosquitoes feed upon them, and when standing closely against a nest with young birds, I have failed to observe mosquitoes feeding, even though they were attempting to seek a blood meal from me with considerable vigor.

FIGURE 17

Arctic Ground Squirrel (Spermophilus undulatus)

In the tundra regions on windless days, mosquitoes curtail the activity of this animal by the eagerness with which they attack. Of the rodents, this squirrel is thought to be the most important animal host for "tundra" mosquitoes.

mosquitoes around them. Occasionally they will brush their ears and nose with their forepaws, possibly in an attempt to free themselves from some of the mosquitoes. When the varying hare population is low, then it cannot contribute a significant amount to the feeding ecology of subarctic mosquitoes, and there are as many "lean" years for this mammal as there are years of abundance.

Certain mammals, such as the caribou and the moose, are found with the taiga, but I have never had an opportunity to observe a sufficient number of these animals at close range to ascertain how important they might be as a source of blood for the mosquitoes. I have observations of one caribou in the arctic tundra which I will mention later, but this is an isolated case and I think it unsafe to transliterate from the tundra to the taiga in any event. I have had trappers and big game guides tell me that they have seen moose very distracted by the persistent attacks of mosquitoes, and I can well imagine that this is so. During earlier years at the Arctic Aeromedical Laboratory, several bears were housed in cages, and I know that Aedes communis, Aedes punctor, Aedes excrucians and Culiseta alaskaensis would feed on these animals with considerable avidity.

Feeding Habits of Arctic Mosquitoes

To obtain information about the feeding habits of arctic mosquitoes, the following study in the field was undertaken. It was decided to go by rubber raft along the Colville River from Umiat to where it empties into the Arctic Ocean. To make such a trip feasible, I am deeply indebted to the administration of the Arctic Aeromedical Laboratory for releasing MSgt Freeman White and SSgt James Williams to assist me in this endeavor. Sergeant White had had previous experience in the area and without his knowledge in handling the rubber rafts and knowing the Colville, the trip would not have been possible. This study was slightly more than two weeks in duration and was scheduled for the middle of July, a time thought to coincide with the peak of the arctic mosquito season. Feeding observations were made at Umiat for a period of three days, at the mouth of the Anaktuvuk River one day, at Big Bend one day, Ocean Point three days, and the mouth of the Colville River six days. From these studies, data were obtained for the basis of the concept that five species constituted the mosquito population of the Eskimoan Biotic Province. At the first three collection sites previously mentioned, all five species were encountered. However, at Ocean Point Aedes impiger and Aedes nigripes were the most abundant, with Aedes punctor and Aedes hexodontus performing a relatively insignificant role. No specimens of communis were observed there. Man was used as the attrahent host in all cases. The densest population of mosquitoes that I have ever encountered in either the arctic or subarctic was encountered at the mouth of the Anaktuvuk River. During a 15-minute interval, 1,253 mosquitoes were removed from the forearm of an experimental subject. This was an area corresponding to the 54 square inches mentioned previously in the biting studies at Nordale Woods, and the feeding

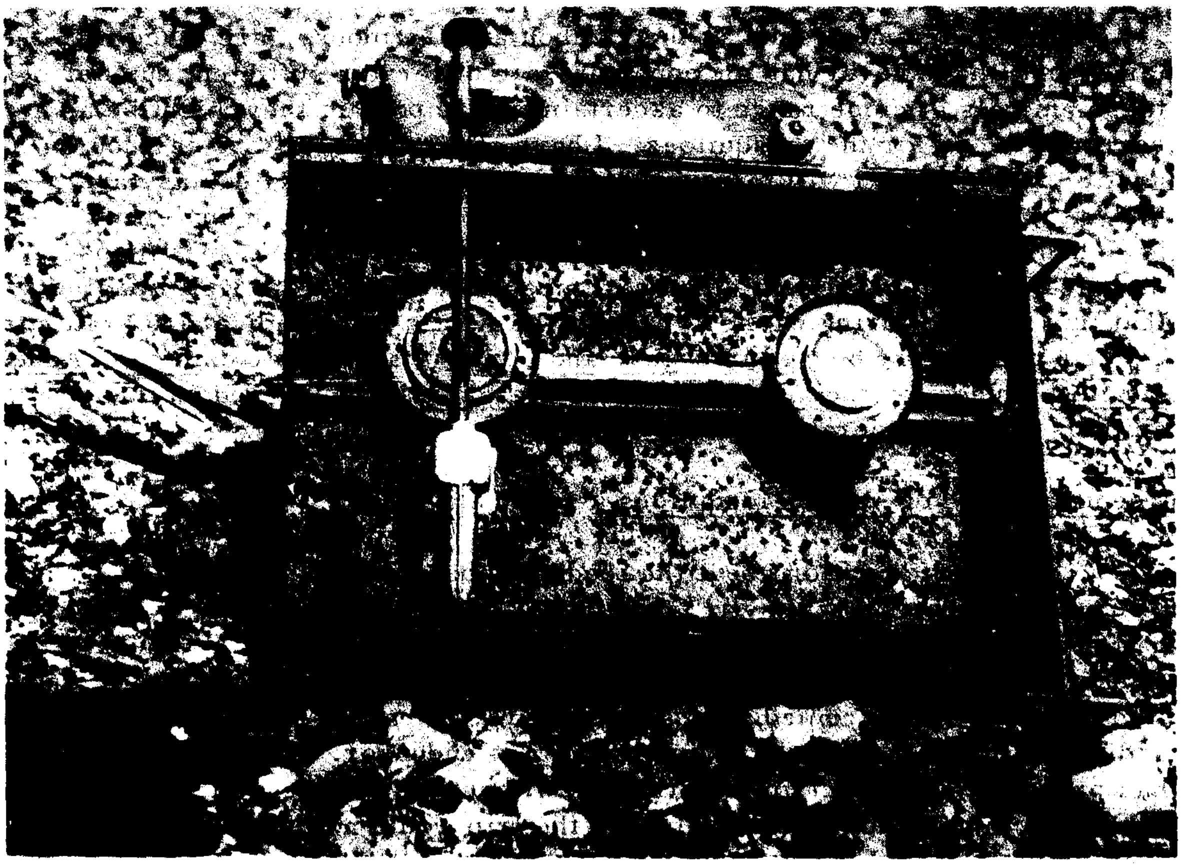

FIGURE 18

Dead Mosquitoes in Bottom of Coleman Stove after Cooking One Meal

Usually, the dead mosquitoes would pile up sufficiently deep to "burn out" three times in the process of preparing a meal This is the residue after three such burn-outs. Photo taken July, 1962, Big Bend, Colville River.

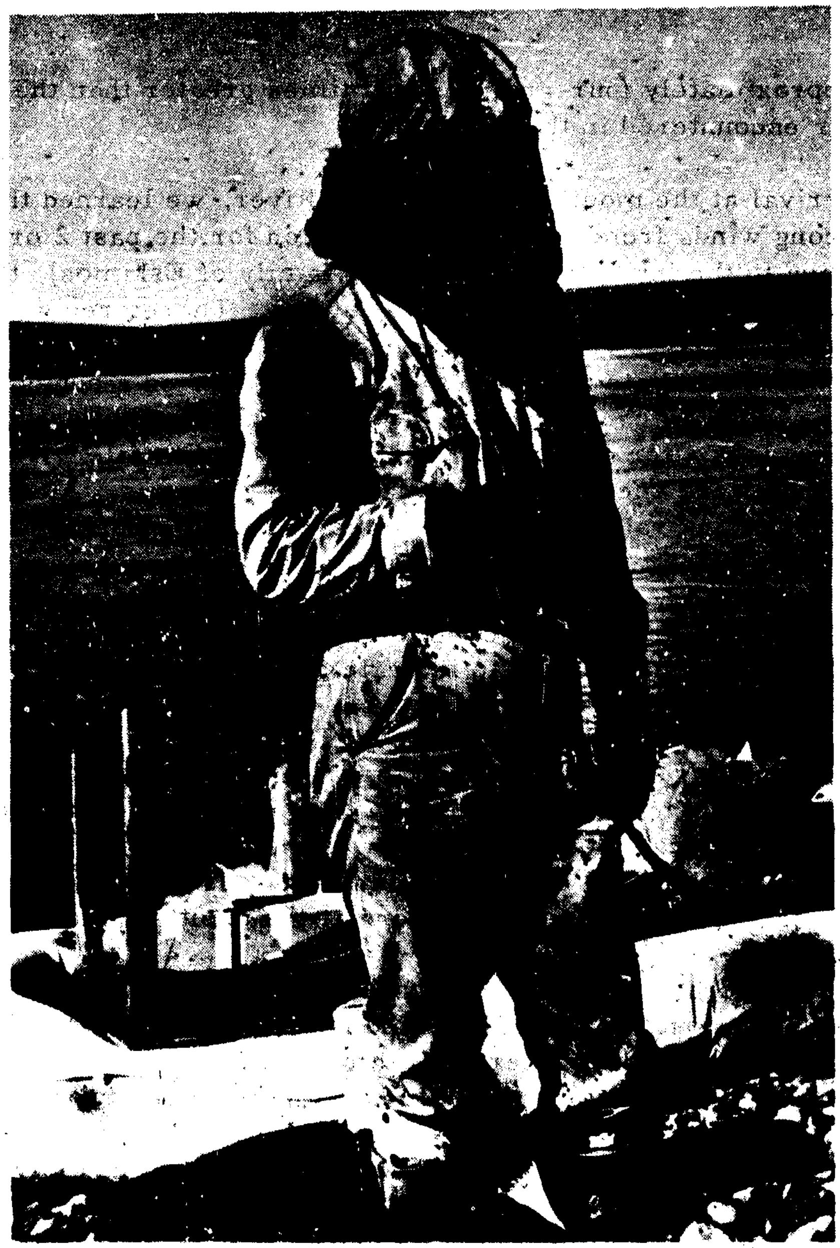

FIGURE 19

Mosquitoes Swarming Around the Author at the Mouth of the Anaktuvuk River

On 54 square inches of exposed forearm, 1,253 biting mosquitoes were collected in 15 minutes. The forearm was swollen approximately one third above normal size for 36 hours, after which the swelling subsided with no ill after-effects.

rate was approximately four-and-one-half times greater than the highest number ever encountered in the subarctic.

Upon arrival at the mouth of the Colville River, we learned that there had been no strong winds from a southerly direction for the past 2 or 3 weeks and that according to the inhabitants (one small family of Eskimos), the adult mosquitoes had emerged within the past 10 days. Therefore, we were able to gather a relatively large sampling of mosquitoes with a feeling that they belonged to the immediate area and had not been carried a considerable distance by the winds, as can sometimes happen in the tundra regions of the far north. Three days after arrival at the mouth of the Colville River, strong southerly winds were encountered that lasted for 48 hours. After the wind subsided, the feeding rate of the mosquitoes was nearly double that previous to these winds. Prior to the southerly winds, we had encountered only two species of mosquitoes, *Aedes impiger* and *Aedes nigripes*. After the winds, we had four species, thus giving us almost a full complement of arctic mosquitoes again. This would seem to indicate that the mosquitoes had been blown from the south for a considerable distance. Our studies indicated that the tundra mosquitoes were able to tolerate winds more than double that known for the taiga mosquitoes. They were found to bite on the leeward side of one's anatomy in a wind up to 12 miles an hour. We also found that feeding took place at 42° F, although the feeding rate was much lower than when a higher temperature from 55° to 65° F was encountered. The latter temperature was the highest one encountered while we were at the mouth of the Colville River.

Within the tundra, I think that the caribou furnishes a considerable source of protein for the mosquito. I have talked with Dr. W. O. Pruitt, and he has indicated that for some days after a large caribou herd has passed through the tundra, one is not bothered by mosquitoes. I have one or two observations from our trip along the Colville River that lead me to believe that the mosquitoes do feed extensively upon the caribou. We saw one bull, with his horns still in soft velvet, that had fallen into a small canyon along the river and apparently was unable to climb out. We approached him closely and, with the aid of field glasses, noted that his horns were completely covered with mosquitoes in various stages of engorgement. I think the caribou calf, with its very short coat, would be particularly vulnerable to the mosquitoes. Natvig (103) describes very graphically the way in which mosquitoes seek the reindeer in the Scandinavian Arctic. Where the caribou occur in large numbers, I feel that mosquitoes have no problem in securing the single blood meal which they seek in the Arctic. The migratory habits of the caribou also would aid in providing a source of food for the adult mosquitoes within a very broad range.

Phenological Data

As indicated earlier, weather is of extreme importance in affecting the activity of an adult mosquito, even though these boreal creatures are

remarkably well adapted to their rigorous environment. Of the various elements of weather that were studied in this investigation, temperature was found to be the most important during a 24-hour period. Light is of considerable importance at the lower latitudes, and all species in that environment are largely crepuscular; however, this is not the case in the boreal region because the habitat is modified by the almost continuous periods of light during the mosquito season. I do not agree with Gjullin et al (51) who indicate that greatest activity tends to coincide with what would ordinarily be the twilight period. I base this concept upon our 24-hour biting studies in Nordale Woods, where during the darkest period (2330 hours) if the temperature compared favorably with that earlier in the evening, this was the time when we could get as high a biting rate as at any other period. Be that as it may, the factors affecting the feeding activity of the female mosquito are reasonably well established, but they never function independently and the interrelationship of their combinations is difficult to interpret. I consider temperature, wind, relative humidity and light (in that order) to be the most important.

Our studies at Nordale Woods indicated that mosquito activity was almost nonexistent below 46° F and ceased about 80° F, with the possible exception of Aedes excrucians which would feed during the bright sunlight when no other mosquito was active. The optimum temperature appeared to be approximately 65° F. At the mouth of the Colville River the mosquitoes showed considerable activity at 42° F but were not particularly active when the temperature exceeded 65° F.

Mosquitoes in the taiga will almost cease activity when the wind speeds are above 5 miles per hour; they are noticeably influenced at a rate of 3 miles per hour. However, in the tundra the mosquitoes are not affected by a rate of 5 miles per hour, and I have noticed little difference in their feeding habits until the wind approached approximately 8 miles per hour, when a rather sharp drop was encountered. However, a reasonable number continued to bite up to and including wind velocity of 12 miles per hour.

With relation to the relative humidity, we were unable (as were Gjullin et al., 51, and Pratt, 110,) to show any clear correlation between relative humidity and the mosquito activity. In working on Canadian species of Aedes in the field, Brown (21) observed that when the temperature was above 15° C (59° F) moisture was the chief attrahent factor. Hocking et al. (66) converted their humidity data to saturation deficiency values and were then able to demonstrate a correlation with feeding activity. I have been able to compile only a small part of my humidity data on this basis, and thus I will have to accept the values reported by Hocking. Hocking felt the effect was somewhat delayed, with the peak figures rising shortly after a fall in saturation deficiency and falling shortly after a rise. On the other hand, Platt et al. (109) concluded that they had shown a 100% positive correlation (in nature) between

relative humidity and the abundance of Aedes vexans throughout the night, regardless of elevation, time of night or habitat (woods or open field). According to these authors, the optimum humidity for most of their study period was 70%; the range was 60 to 90%. Inasmuch as Platt et al. did this work in Georgia, the temperature factor apparently did not exert as strong an influence as it does in the subarctic, where almost each night there are a few hours when the temperature is low enough to curtail the activity of the mosquitoes (even though the relative humidity simultaneously reaches its highest peak at this time).

Insofar as the inversion of temperature factors is concerned, various authors, among them Gjullin et al. (51) have discussed the importance of this in the feeding activity of the mosquitoes and have termed it "lapse rate." According to them, when an extreme inversion condition was present (as for example, when the temperature at 5 feet above the ground was below 45° F and the warmer temperatures were above head level) no mosquitoes were found at body level, but they were seen flying in the warmer air overhead. I do not know what to make of their data, but I do know that in our study of vertical distribution at Nordale Woods, we had some excellent temperature inversions and still the numbers of mosquitoes encountered in the bait boxes at the upper levels were considerably lower than those on the lower levels. It may well be that our problem here lies in the fact that when this occurred, the temperature at 3 feet above ground was not below 45° F.

Many entomologists have speculated about how such huge populations of mosquitoes can occur year after year in the northern regions, thinking that it would be impossible for all of them to obtain a blood meal. Hocking (65, 67) reported that Aedes communis did not attempt to seek a blood meal, but that an histolysis of the flight muscles occurred, furnishing enough energy for the female to deposit a small number of eggs. My own data in several regions of Alaska do not support these concepts of Hocking's. In fact, in certain areas (for example, Anaktuvuk Pass) Aedes communis was one of the most abundant blood seekers. In fairness to Hocking, I must admit that in other areas I had found this mosquito quite reluctant to feed when other species were willing to bite with considerable vigor. In most respects my concepts agree with Beckel (6). Indeed, with so little knowledge of the adult mosquito feeding habits and the fact that what is known now appears to be conflicting, this problem must be approached from several aspects.

Hocking et al. (66) reported that feeding on nectar was a "universal habit" among the female mosquitoes at Fort Churchill, Manitoba, Canada. They found that at least 74% of the mosquitoes attracted to man in the middle of July in 1948 had fed on the common woods orchid, Haberaria obtusata. These investigators observed that as the season progressed, the majority of mosquitoes attracted to man carried eggs in various stages of development, and they doubted that many of them could have had a blood meal.

It is an established fact that some mosquitoes can lay viable eggs without having a blood meal, as one can readily ascertain from the numerous reports in the literature of such famous mosquitoes as Aedes aegypti. One of the first notable experiments along this line was that of Trembly (137), in which she raised 26 generations of Aedes triseriatus in the laboratory without a blood meal. Going back to Hocking's (ibid) concepts, he indicated that with the autolysis of flight muscles in Aedes communis, there was a concurrent increase in ovarian development. According to Hocking's evidence, the average number of eggs produced by such a mosquito was 65 and the maximum 93. He could find no evidence of blood feeding in this form of Aedes communis. On the other hand, Beckel (6) working in this same area (Fort Churchill) found no autolysis in the flight muscles in this or any other species he studied. Beckel also indicated that Aedes communis had a large fat body similar to the Anopheles mosquitoes in the Mediterranean regions, in which gonotrophic disassociation occurs. Apparently Aedes communis draws on this fat body for the production of eggs, while other boreal mosquitoes studied simultaneously cannot, even though one is present. As a result of these observations, Beckel believes that the blood meal is still the most probable source of protein for egg development. I think, without question, that the mosquitoes that do have a blood meal will lay a larger number of eggs than those that have depended upon pollen as a source of protein. At a recent national meeting, Hocking presented evidence to indicate that flower feeding by northern mosquitoes was considerably greater than many individuals had been led to believe in the past. By inserting a thermistor in the arctic poppy he was able to show that there was an increase in the temperature of as much as 6° F within the parabola formed by the petals of the flowers. Much more information is needed on this fascinating subject.

V

COLONIZATION OF SUBARCTIC MOSQUITOES

After considerable deliberation, it was decided to put major emphasis on the colonization of two species of subarctic mosquitoes, both because of their extremely broad distribution in areas other than Alaska and, because they represented two distinct types of life cycles. The species selected were Culiseta alaskaensis and Aedes excrusians. At the beginning I was not completely convinced that the information reported about the feeding habits of the former species was entirely accurate, but Culiseta alaskaensis did offer the best chance among the subarctic mosquitoes for a species probably seeking more than one blood meal. Due to the broadness of the distribution of Aedes excrucians, I had hoped that we might find a similar phenomenon with this mosquito. Also, since Aedes excrucians occurred during the warmer months of the year as an adult, there was some thought that it might possibly be more important in the maintenance of viruses or other pathogenic organisms than most of the black-legged species which come off early

in the spring when the temperatures are relatively low — so low in fact that probably no virus would complete an extrinsic incubation period in the invertebrate animals.

Culiseta alaskaensis

During the summer of 1960, surveys were conducted at Circle Hot Springs, Fairbanks, Olnes and Paxson Lake area in an attempt to locate a dense breeding population of *Culiseta alaskaensis*. Initially we had some difficulty in selecting a particular type of habitat that we felt would be the most likely one in which to find this mosquito, because reports from the literature were entirely conflicting. For example, Frohne (35) reported that most of the stocks he had attempted to colonize were found in a very small temporary pool of water with an extremely high organic content. However, most of the literature indicated that this species bred in permanent pools where the water is clear, etc. Be that as it may, intense numbers of egg rafts and larvae were found in a small temporary pool at Olnes. As Frohne (36) had experienced, this water was also a dark brown color and had a somewhat fetid odor. This proved to be the densest concentration of *Culiseta alaskaensis* that we encountered in our entire experience. For example, 650 egg rafts were obtained within a period of 10 days, and several thousand first, second, third and fourth instar larvae were also collected, not to mention an enormous number of pupae. As the summer temperatures suddenly warmed during the early part of July, the evaporation rate was excessive. We hauled water into the pool in order to keep it going for an additional week but finally had to give up. This pool furnished our stocks for the first year.

Large walk-in reefers of the "Navy" type were furnished by the Arctic Aeromedical Laboratory so that we could maintain a satisfactory temperature inside the buildings. We found that a temperature of 67° F was suitable for the larvae and that the adults were maintained equally well at a temperature ranging from 50° to 65° F. Once the temperature exceeded 70° F we would note a marked increase in the mortality. A relative humidity of 70% was found to be optimum.

Adults which resulted from the wild-caught larvae and egg rafts were maintained alive from July through the end of November. During this period the mosquitoes were packaged and shipped to the University of Oklahoma without any difficulty by utilizing a "bull sperm" box in which 3 pint-size ice cream cartons had previously been loaded with wet ice.

Our initial studies indicated that the size of the cage used to induce mating did not matter particularly, so long as a subdued light was present. We had mating occur in 1-foot square cages as readily as in cages that were three times this size. In the absence of a subdued light (blue bulb), little or no mating seemed to occur, and it was felt an initial successful breakthrough had

FIGURE 20

Oviposition Jar Utilized for Colonization Studies of *Culiseta alaskaensis*.

It was found that a beaker containing a clump of dead grass increased the oviposition rate within a cage by 40%.

been made. (Frohne, 35, reported that he was unsuccessful in his attempt to induce mating, but light conditions were not varied.) There was no indication of swarming, which is not surprising because some of the other species of the genus Culiseta with which I am familiar will mate readily in test tubes, indicating that the swarming behavior may likely not be a necessary factor within this genus.

Raisins which had been soaked and boiled in distilled water and/or sugar solutions were maintained in the cages throughout the period. The mosquitoes fed upon these materials readily, frequently within 3 or 4 days after they had emerged as adults. An occasional female could be induced to take a blood meal within 3 weeks after emerging, but no egg rafts were obtained after these feedings. From September to November the mosquitoes were retained in absolute darkness and at a temperature of 45° F, in an attempt to break up the diapause. On the first of November they were becoming very restless, and the temperature was raised to 65° F. By this time nearly all of the males were dead. The females fed willingly upon the guinea pigs, and egg rafts were obtained within 18 days after this feeding. Approximately 950 engorged females produced 293 viable egg rafts, averaging 202 eggs per raft. Maintained at 65° F, these eggs hatched in 3-7 days. The larvae grew well until the third instar was reached, when a high mortality was noted. This continued throughout the fourth instar and was extremely heavy during the transformation to the pupal stage. By this time it was apparent that even if the remaining specimens were brought through to the adult stage without further loss, considerable difficulty would be encountered in securing enough adults to produce egg rafts for another generation. The adults that were obtained were few in number, smaller than the previous generation and not nearly as active. These adults died within 3 weeks after they emerged, and prior to death none were induced to take a blood meal although they were fed to some extent upon sugar solutions and water-soaked raisins. No egg rafts were secured from them.

Attempts to get the parent stock to take a second blood meal met with some success, but the occurrence was so limited (as was the production of a second egg mass) that no conclusion could be drawn except that it was a relatively unsuccessful experiment.

During the summer of 1961 the population of Culiseta was not nearly as prolific as that of the previous year. The area at Olnes (Figure 21) was watched especially closely, but it never produced more than a small number of larvae during this summer and the summer of 1962. During 1961, there was a virtual absence of adults on the wing during the middle and last part of June. No dense populations of mosquito egg rafts or larvae were encountered during the entire summer of 1961. In part, the lesser density of Culiseta alaskaensis egg rafts and larvae may have been more apparent than real because of the abnormal amounts of standing surface water as contrasted to previous seasons. In other words, the breeding habitats were not nearly as

FIGURE 21

A Clump of Carex at the Study Area in Olnes

650 egg rafts of Culiseta alaskaensis were obtained here within 10 days during July 1960. During the next two summers, only an occasional larva was encountered.

concentrated as in other seasons. With the same total number of mosquitoes spread over the increased surface area, the egg rafts and mosquito larvae would have been dispersed to such an extent that they appeared less abundant.

By diligent searching, other areas were found in which sufficient numbers of larvae were obtained to make further colonization attempts feasible. One such area was Kilarney Lake, located 1-1/2 miles east of the University of Alaska. Here the water was clear, with emergent vegetation consisting of Carex aquatilis, Lemna and Ranunculus. This habitat was a distinct contrast to that of the previous year and is illustrated in Figures 22 and 23. In general aspects, this lake appeared no different from several others within a short radius of Fairbanks, yet the west end of it provided 80% of the egg rafts and larvae for our colonization studies during the remainder of the investigation. The egg rafts were most frequently encountered in the small spaces between the emergent grass and sedges.

The laboratory rearing of the immature stages in the new quarters provided during 1961 and 1962 proved considerably easier. We switched from the large aquaria (30 by 14 by 14 inches) of the previous year and replaced them with polyethylene basins. Large numbers of larvae were reared in basins 15 inches in diameter with a depth of water not exceeding 5 inches. Adult emergence from the pupal stage was also successful. Whereas previously we experienced considerable difficulty during pupation and transformation to the adult stage, mortality was less than 5% under these conditions. It is felt that this phase of the colonization study was successful for many reasons. To avoid the weakness of second generation larvae obtained in previous years, an improved larval diet was made by adding liver extract to ground rat food used the previous season. There are some reports in recent literature indicating that this type of liver extract can be used as a solution in itself to provide adequate food for most mosquitoes. At any rate, we were able to cut down on the amount of organic material added to the larval rearing pans and therefore prevented the "fouling" of the water. In the laboratory, food residues seemed to have a deleterious effect upon the larvae, particularly in the later instars.

Adults were obtained in adequate numbers, although we had considerable trouble with temperature control in the walk-in reefers provided in our new quarters. The temperature in one reefer was so erratic that it produced complete mortality of the adult stocks contained therein. The walk-in reefers available for our mosquito studies during the summers of 1961 and 1962 were much smaller than the old "Navy" reefers used the previous year, and they were equipped with an oversized fan; our subsequent attempts to baffle the currents were not too effective. In addition, the wing of the building containing the reefers was not adequately insulated and as the cold temperatures of the year appeared, it was impossible to keep any semblance of uniform temperature within the reefers themselves. However, in spite of this, we were able to carry the mosquitoes through into the second generation. We were unsuccessful in carrying any colonies beyond this point in 1961.

FIGURE 22

Collecting Third and Fourth Instar Larvae
of Culiseta alaskaensis at Kilarney Lake

Soil sieves were used to obtain the large larvae and pupae. During the summers of 1961 and 1962, most of our mosquito stocks were secured here. This picture was taken during the first week in August, thus the reason for no protective measures against adult mosquitoes.

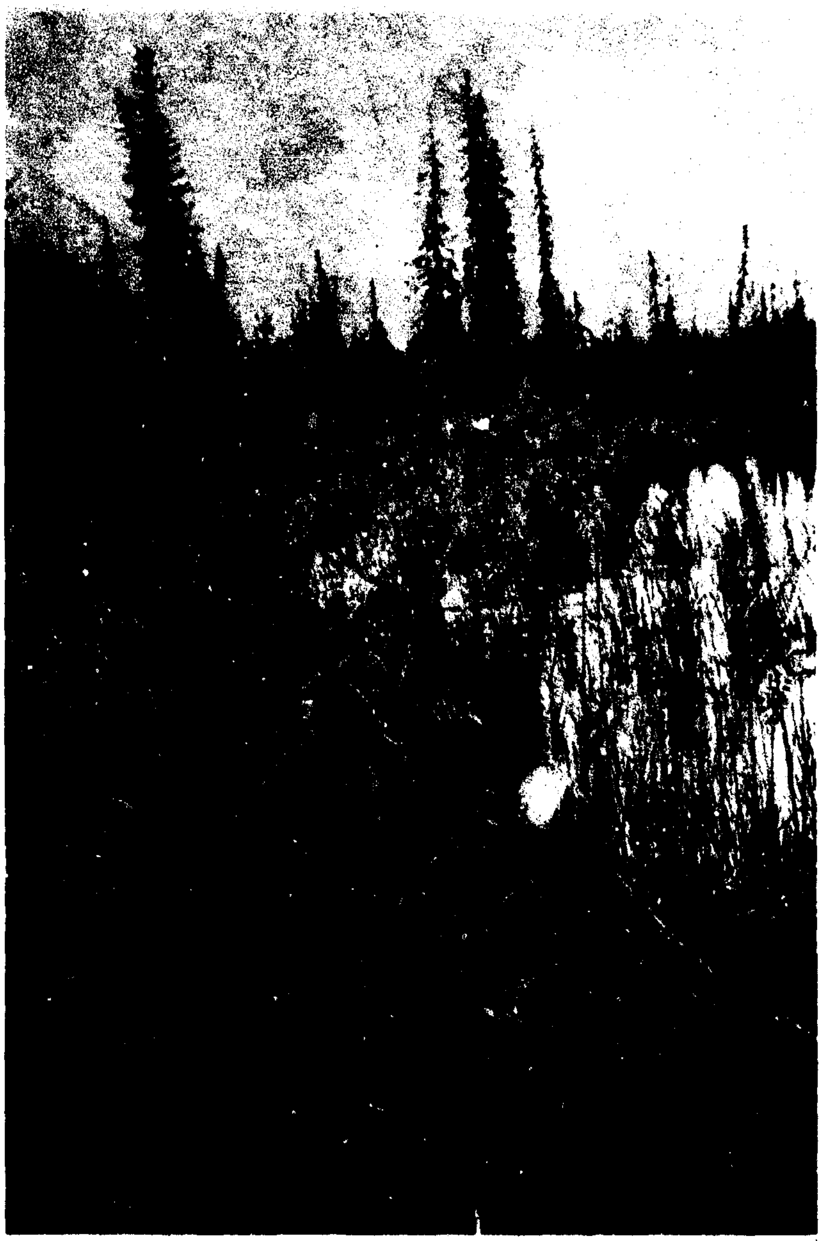

FIGURE 23

West End of Kilarney Lake

Large numbers of egg rafts were secured from among the dead grass in late May. This habitat is a distinct contrast to that of the semipermanent pool at Olnes from which large numbers of egg rafts were taken in the summer of 1961.

Early in 1962, it was decided that if we were to continue to use the reefers for colonization studies the following summer, drastic changes would have to be made in cage structures to eliminate as far as possible the deleterious effects of the air currents generated by the oversized fans. Therefore, all of the screens were removed from the cages and replaced with a heavy polyethylene sheeting. As an additional precaution, an evaporator cooler was secured when more space was granted in the building, and an entire room was set up in which the temperature could be retained at 60° F with a relative humidity of 70%. This room proved much more successful for maintenance of stocks during the summer of 1962 than did the reefers. Mating occurred regularly, and about 2, 500 mated females were shipped to the University of Oklahoma in August. The adults were carried through to the fourth generation in the laboratories at this University, but we could not maintain colonies beyond this point.

Aedes excrucians

Each season several hundred engorged females of this species were placed individually in shell vials to which a small disk of styrofoam plastic had been added. After the mosquito was placed in the shell vial, a small piece of mosquito netting was secured around the top with a rubber band. A few drops of water were added through the netting onto the foam plastic in the bottom of the vial. A boiled raisin was placed on top of the netting to provide a source of food other than blood.

We were confused by the laboratory results obtained with this mosquito because a high percentage (67%) of the adults died after the first oviposition. Routinely, a small percent of the specimens required a second blood meal and, on rare occasions, required a third one before they oviposited for the first time.

We secured a limited number of observations where a second mass of eggs was produced after a second or third blood meal, although in this instance considerably fewer eggs were laid than during the first oviposition. Ordinarily these mosquitoes laid, on an average, 115 eggs per mass. Those obtained from a second laying averaged 35.

The eggs that were obtained were allowed to be conditioned (the foam plastic disk allowed to dry over a period of days) and then stored in a cabinet with a high relative humidity (80%) and left for 2 months at 20° F. The eggs were then flooded with water, and we were able to secure a large number of larvae which could be reared without too much difficulty. However, we were never able to produce mating in captivity, and since swarming has been indicated for this genus, we apparently would have had to have a cage of huge dimensions in order for this to possibly occur. This type of laboratory manipulation was not feasible under our limited facilities. In short, our experimentation with this particular mosquito was a relatively futile one;

mention of this will be made later when the zoonotic relationships are discussed.

VI

OBSERVATIONS OF THE BIOLOGY OF CULISETA ALASKAENSIS

Frohne (36) laid the basis for the study of the natural history of this mosquito. His observations were made with considerable insight and clarity and most of what I have to report probably reflects differences in the climatic conditions in the interior of Alaska as compared with those known by Frohne in the environs of Anchorage. The first adults appeared on the wing on 26 April 1962. The first egg rafts were encountered in Kilarney Lake on 16 May. This was not just an occasional raft but considerable numbers. Therefore, I presume that some must have been laid prior to this time. Figure 24 shows some of the rafts that were taken at this time, certain of them illustrating their characteristic pointed shape. In general, the egg rafts were found associated with the dead *Carex aquatilis* and within a week after we found the first ones we were able to secure six or seven at a time when utilizing a shallow flat pan for dipping. In general, egg rafts are evident throughout July but by the latter part of the month become extremely scarce. Figure 25 is a photograph of a semipermanent pool where egg rafts were collected as late as 26 August 1959. Insofar as I know, this is the latest appearance of rafts for this species. At that time six were secured, yet no further specimens were obtained by the end of the first week in September.

Larvae appear as first instars during the latter part of May and usually reach a peak from the middle of June to the middle of July. The larvae have never been taken in water that was cooler than 45° F. In other words, the larva appears to be adapted to warm water and it always seems somewhat amazing that the adult is cold-tolerant enough to survive the winters. Waters that were from 50° to 60° F generally seemed best for the development of this species in nature.

One of our principal goals in the study of the biology of *Culiseta alaskaensis* in nature was to learn as much as possible about the adult behavior, not only because this was an area in which so little was known, but because we felt it would provide insight into our attempts at colonization. Therefore, considerable energy was expended in attempting to find resting places for the adults that had emerged early in the summer. One did not see them on the wing during the latter part of June, July and the early part of August when we knew they were emerging in considerable numbers. By coincidence we found that many of them would reside in the burrows of the bank swallows (especially during the month of August). At this time, the bank swallows (*Riparia riparia*) had essentially abandoned the burrows and were assembling in migratory flocks. Originally, I had hoped that we had stumbled

FIGURE 24

Egg Rafts of <u>Culiseta alaskaensis</u> in the Latter Part of May, 1962

Typically, the raft has one end that tapers to a slender point. The more rounded ones were undoubtedly broken in handling.

FIGURE 25

Temporary Pool at Olnes

This small pool contained egg rafts of Culiseta alaskaensis as late as 24 August in 1959. Photo taken in May, 1962

upon the habitat in which the mosquitoes overwintered, but as the study progressed on this particular habitat, I could draw no other conclusion than that the burrows were used during the warmer months as estivation sites and then abandoned as the colder temperatures and shorter days appeared during the latter part of August. This would comply with the findings of Harwood and Halfhill (56). Other burrow habitats were investigated, largely because of Harwood's report (55) of finding mosquitoes overwintering in mammalian burrow systems in the Pacific Northwest. Knowledge concerning the microclimate in such burrow systems is not extensive; however, Mayer (100) has reported interesting data regarding the temperatures for burrows of the arctic ground squirrel. He states that the lowest recorded temperature in the burrow systems was 16° F, with a maximum range in temperature of 15.2° F. Snow cover or burrow depth in excess of 30 cm did not offer appreciably better protection than a lesser amount of snow or a shallower burrow. These temperatures agree reasonably well with those obtained by Pruitt (113). Therefore, an emergence trap was designed as illustrated in Figures 26 and 27, to be placed over the burrow of the arctic ground squirrel. During October of 1961, 75 such traps were placed over burrows in the Paxson area, and later in the month, 150 were placed over burrows of this squirrel at Circle Hot Springs. They were checked the following May, and while successful in capturing a large number of dipterous insects, the results with mosquitoes were not spectacular. However, we do not know the efficiency or the favorability of this particular burrow habitat for the overwintering of Culiseta alaskaensis as yet, because we had not anticipated that spiders would gain entrance to the traps. This did happen, and the spiders destroyed a considerable number of insects, among them some mosquitoes. All that can be said at this time is that the burrow is used, but we cannot say to what extent. I am not of the opinion that it is a significant source for overwintering fo adult mosquitoes of this species.

During late August and early September, one notes a reasonable number of Culiseta alaskaensis resting on the outer walls of buildings. However, a search of the vacant prospectors' cabins and various empty buildings during the colder seasons of the year met with no success in attempting to secure the adult mosquito, although an occasional specimen of Anopheles earlei was encountered. The same is true of the tree cavity illustrated in Figure 28. This type of habitat is not abundant in Alaska, and therefore, even if adults had been found, this particular niche could not have been considered as a significant source. During October, bark was stripped from both dead spruce and birches, and although a tremendous number of nematocerous Diptera were secured, no mosquitoes were among them. Early in the spring, the same procedure of bark stripping was repeated, and a large number of immobile, small Diptera were again collected, but no mosquitoes were encountered.

In an attempt to gain some impressions of the movements of this mosquito, during late August and September a series of standard New Jersey light traps were placed in operation at various sites and at different

FIGURES 26 and 27

Emergence Trap Placed over a Ground Squirrel Burrow
to See if the Burrow Habitat was Used as a
Hibernaculum by _Culiseta alaskaensis_

The traps were placed in position late in October and checked in May of the following year. It is not certain how important this habitat is for the overwintering of this mosquito, because a large number of spiders also entered the traps and destroyed many of the insects collected. However, it is known that the burrow is used; for example, one such trap contained six of these mosquitoes.

FIGURE 28

Cavity at Base of Cottonwood Tree

Habitats such as this were checked as overwintering sites for Culiseta alaskaensis, but without success. However, an occasional specimen of black fly was encountered as late as November in this cavity.

elevations from the ground. Most of our specimens were obtained at traps located in the positions shown in Figure 29, in which the entrance to the trap was not more than 3-1/2 feet above ground. The trap in the lower lefthand corner at ground level continued to secure adults for a much longer period of time — in fact, throughout September — even after killing frost had occurred. This provided a possible clue to the whereabouts of this mosquito's overwintering site. A check was made of a good-sized stand of Calamagrostis canadensis grass (Figure 30) not far from the laboratory. By cutting the clumps at the base with a sharp, modified chisel (spud) and placing the grass in large plastic bags, I was able to secure a reasonable number of adult mosquitoes after allowing the material to stand in the laboratory at room temperature for several hours. Checks of this sort were made periodically throughout the winter, and as late as March of 1962, adults were secured from clumps of Calamagrostis under the snow at the study site in Wilbur Creek. On the basis of this evidence, I think that probably certain species of tall grass provide enough shelter and protection for the mosquito so that it can carry out the overwintering process. As indicated earlier, Pruitt's study indicated that the temperature underneath the snow (once 19 cm have accumulated) does not drop lower than 16° F. Therefore, the mosquito does not have to withstand the rigorous temperatures that occur above the snow.

Overwintering in such a habitat has an additional advantage to the mosquito in that the snow generally melts around the clumps of grass earlier than it does in the heavily wooded areas. Therefore, the mosquito is released to activity early in the spring.

Recently Sommerman (127) reported on certain activities of Culiseta adults in the Anchorage area. It will be interesting to see if the resting sites she observed in the cliff and talus habitats are also the overwintering sites for these mosquitoes. From my observations in interior Alaska, I do not think this will prove true for C. alaskaensis.

I have had prospectors relate that they have seen the tunnels of some of their mine shafts literally gray with what they call the "large snow mosquitoes." If, indeed, these were mosquitoes that they saw, most likely they were members of the genus Culiseta. However, this is an artificial type of habitat, and Culiseta alaskaensis existed long before the coming of prospectors. I have made no attempt to examine this type of habitat and therefore can neither confirm nor deny their verbal reports. However, these individuals were surprisingly knowledgeable about the ecology of many things and seemed sincere. On the other hand, no one wants to please more than certain of the loquacious old prospectors. They are artists without peer among story tellers!

Culiseta alaskaensis is not an aggressive feeder when compared to the Aedes species of the subarctic. The bite of this mosquito, in our experience,

FIGURE 29

New Jersey Light Traps, Conventional Instruments of Mosquito Studies Further to the South, Were Not Particularly Useful Here.

From late August through early October, the trap at ground level in the grass collected a reasonable number of Culiseta alaskaensis, whereas the other two traps seldom attracted mosquitoes at this late date.

FIGURE 30

A Stand of Calamagrostis canadensis near Laboratory

Culiseta alaskaensis was observed migrating into this type of habitat in late August and early September 1961. Clumps of this grass removed and placed inside mosquito cages in the laboratory the following spring yielded a number of female Culiseta alaskaensis. I was able to get these adults to feed after being retained in the laboratory for 8 days.

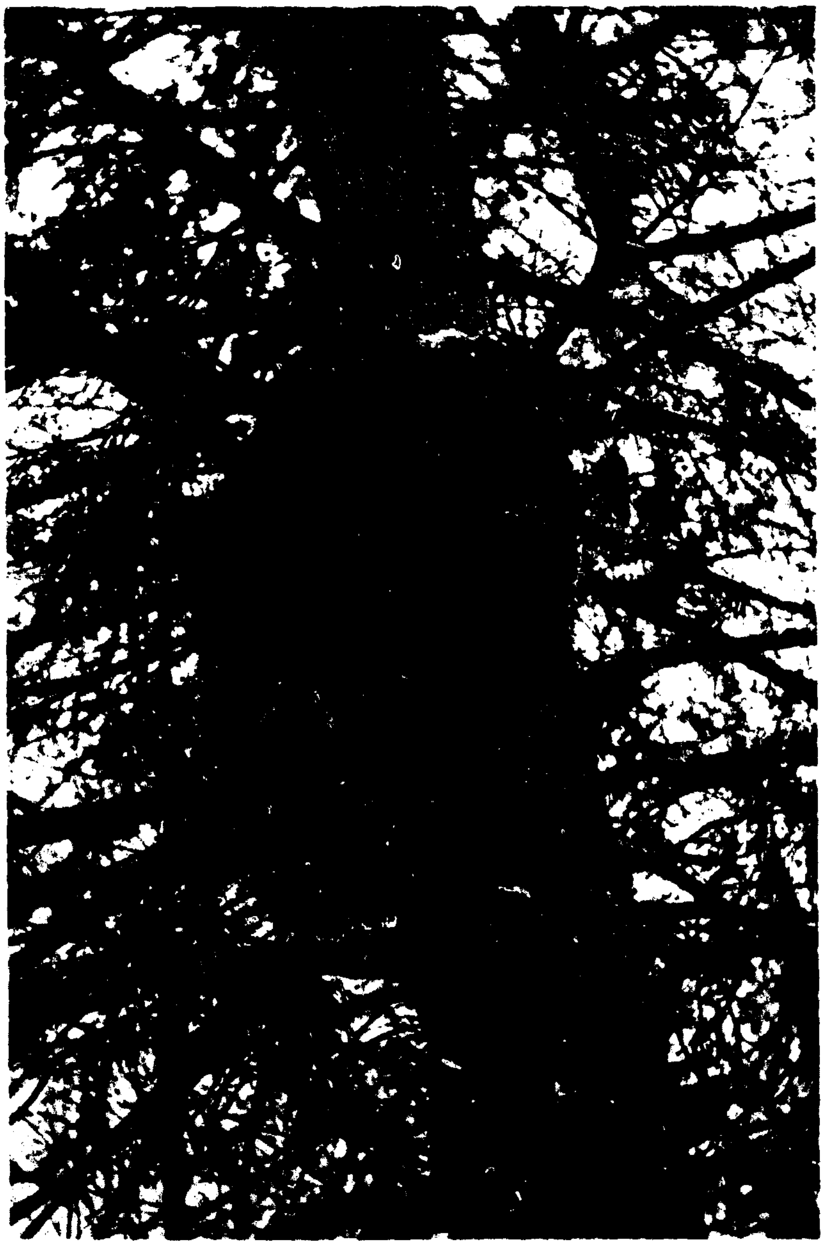

FIGURE 31

Nest of the Red Squirrel (Tamiasciurus Hudsonicus) Was Checked as a Possible Over-wintering Site for Culiseta alaskaensis

This species was not found, although an occasional specimen of Culex territans was obtained as late as February. Photo taken at Circle Hot Springs October 1961.

was the least noxious of any encountered within the taiga. The mouth parts apparently are not as sturdy as those of many other species of mosquitoes, as shown, for example, by its inability to pierce the skin on the palm of the hand. When feeding on the forearm, several specimens would have to make several attempts to get the proboscis fully inserted. Until a favorable site was found, the attempt at feeding was characterized by a bending of the proboscis in any one of several directions. When allowed to select a feeding site on humans, this species almost invariably would feed at or near the hairline on the scalp.

Most Aedes mosquitoes were completely engorged within 1-1/2 minutes, but C. alaskensis required 3-1/2 minutes to engorge. I have some observations in which certain specimens required as long as 11 minutes to become replete.

C. alaskaensis is one of the most difficult mosquitoes to feed in captivity, as the following experience fully illustrates. In May of 1962 the adults were especially numerous in Nordale Woods and were feeding reasonably well upon the shaved abdomen of an immobilized laboratory rabbit. Several hundred specimens were collected by means of an insect net and placed in cages for transportation to the laboratory, with the intent of introducing various animals into the cages to gain additional information on feeding habits. However, the mosquitoes did not comply, virtually all of them refusing to feed on any of the animals. Some of these adults survived in a constant temperature cabinet until the first week in August but still refused to take a blood meal. This was especially surprising since the feeding response seemed to have been stimulated at the time they were collected.

VII

ZOONOTIC RELATIONSHIPS

Knowledge is meager about what diseases may be transmitted to man by northern arthropods. Phillip et al. (108) and Hopla (69, 70) have presented the only evidence thus far that arthropods are involved with diseases in nature transmissible to man in the subarctic regions of Alaska, and their evidence was actually an indirect relationship with tularemia and the rabbit tic (Haemaphysalis leporis-palustris). The only reference to mosquitoes applicable in this regard was reported by Olin (105) in Sweden. In this study, epidemiological evidence and isolations of tularemia organisms from Aedes cinereus led him to believe that it was the actual vector to man. This was an interesting observation because this particular mosquito is Holarctic in distribution. In fact, it can be found in the high montane elevations as far south as central Utah. The observation is also of interest because this is the mosquito which is considered to be single-brooded and seeks but one blood meal. While not an abundant mosquito in Alaska, it does occur routinely in the central part of the state.

Interesting as the study of tularemia may be, our interest here was in the arthropod-borne encephalitides (arbo-viruses). Insofar as is known, no

human cases of this group of diseases have been reported in Alaska; however, there were perfectly valid reasons for such an investigation to be started. For example, the majority of people in Alaska are either directly in the military service or associated with it as civilians. There is no civilian agency in the past history of the state that has undertaken the burden of investigating this type of problem, although since this study was inaugurated, the Arctic Health Research Center at Anchorage has become active in this field. Also, when our tularemia investigations (69) were started, only two clinical cases of the disease had been reported in the state, and many people felt that the investigation was unwise. However, our studies showed that up to 17% of the native population in certain of the villages had had previous experience with the disease.

This investigation was based upon the thesis that the arbo-viruses were possibly introduced into the subarctic regions of Alaska each summer season by migrating birds and that viruses related to Powassan virus probably occur in the nonmigrating mammals, especially rodents. It would have been impossible for a group as small as this to have carried out a study without the cooperation of the Rocky Mountain Laboratory, U. S. Public Health Service, Hamilton, Montana. Arrangements were made with Dr. Carl Ecklund, principal virologist and Dr. David Lackman, principal immunologist, to carry out the laboratory phases of the program. In addition, the Cooperative Research Unit at the University of Alaska, under the direction of Mr. Robert F. Scott was able to supply us with additional support in the study area itself, principally by furnishing boats, lodging and manpower to aid in the capture of birds.

The Minto Flats area was selected as the location best suited for the possible occurrence of arbo-viruses in Alaskan avian fauna because it is an area that is known to support a large breeding population of migratory aquatic and shore birds. Circumstantial evidence, according to Hess and Holden (61), exists for western equine encephalitis being spread in these birds. This virus has a wide distribution in the New World and according to Miles (102) is known to occur as far north as the southern provinces of Canada and as far south as Argentina and Chile. In Canada, the virus is now known to occur as far north as the southern part of Hudson Bay and has been found in the provinces of Saskatchewan, Manitoba and Ontario. Since all three of the above-mentioned Canadian provinces are located in the Hudsonian Biotic Province as defined by Dice (25) — which also includes the study area at Minto Flats — it did not seem too improbable that arbo-viruses might occur this far north. In addition to the bird population, the summer temperatures at the Minto Flats area ought to be as conducive for the extrinsic incubation of a virus within the mosquito as any area in Alaska. This area also supports heavy populations of mosquitoes.

After due consideration, it was decided to use pyrex test tubes 15 by 125 mm for storage of all tissues. This complicated the sealing process but

it was found that a "Presto-lite" type B acetylene cylinder (shown in Figure 32) and a size 3 torch stem made it possible to seal the tubes rapidly enough that little if any heat was conducted down the walls of the tubing, thus avoiding damage to the specimens contained within. A small vice, which could be placed on a camp table, made it possible to free both hands of the operator, thus facilitating the sealing of the tubes. This equipment does not weigh over 35 pounds, so it is mobile and can be handled easily under field conditions. A regular supply of dry ice was obtained from the Industrial Air Products Company of Fairbanks. A polyfoam plastic container 29 by 18 inches with 2-inch walls was selected as a retainer for the dry ice and storage for the specimens in the field after the tubes were sealed. With the judicious use of sawdust, it was feasible to add 35 pounds of dry ice to this container once a week and rest assured that there would still be sufficient ice left at the end of the week to keep the specimens in good condition. If need be, this amount of dry ice could have been depended upon reasonably well for a period of 10 days, and it was subsequently found that 50 pounds of ice would insure safe operation for 14 days.

Disposable 5-cc syringes with 20-gauge needles were used to secure blood samples from the brachial veins of the fowls and from the hearts of the rodents. This greatly simplified the use of sterile equipment in the field and saved a considerable amount of time, which was of essence in such studies. Three hundred and fifty samples of blood and serum were obtained from various species of ducks in the Minto area and sent to the Rocky Mountain Laboratory, Hamilton, Montana. Assay of this work was negative. It was indeed unfortunate that a larger series of specimens could not be secured from the birds, but due to the extremely high waters in the Minto Flats area, the traps operated by the Alaska State Department of Fish and Game were not as efficient as under normal operating conditions.

A number of blood and serum samples were obtained from various small rodents and from the arctic ground squirrel. However, these tissues were not sent to the laboratory for assay work because the cold temperature cabinet in which the specimens were stored shorted out during our absence on a field trip. All of the tissues were completely thawed and the blood hemolyzed upon return to the laboratory, rendering them useless for laboratory study.

Extensive observations of the ectoparasites of rodents in Alaska would indicate that insofar as the central and northern portions of the state are concerned, little or no chance exists for the transmission of arthropod diseases to man, by these arthropods. We must keep in mind Olin's concepts in regard to <u>Aedes cinereus</u>, but my observations of the past 3 years on the feeding habits of Alaskan mosquitoes leads me to believe that often they do not secure more than one blood meal. If they were to be effective in the transmission of a disease to man, it could only be through an interrupted feeding. For insects to be effective vectors by this means would only occur under the most fortuitous circumstances. With this thought in mind, I think results such as those published by Highby (63, 64), in which he utilized such

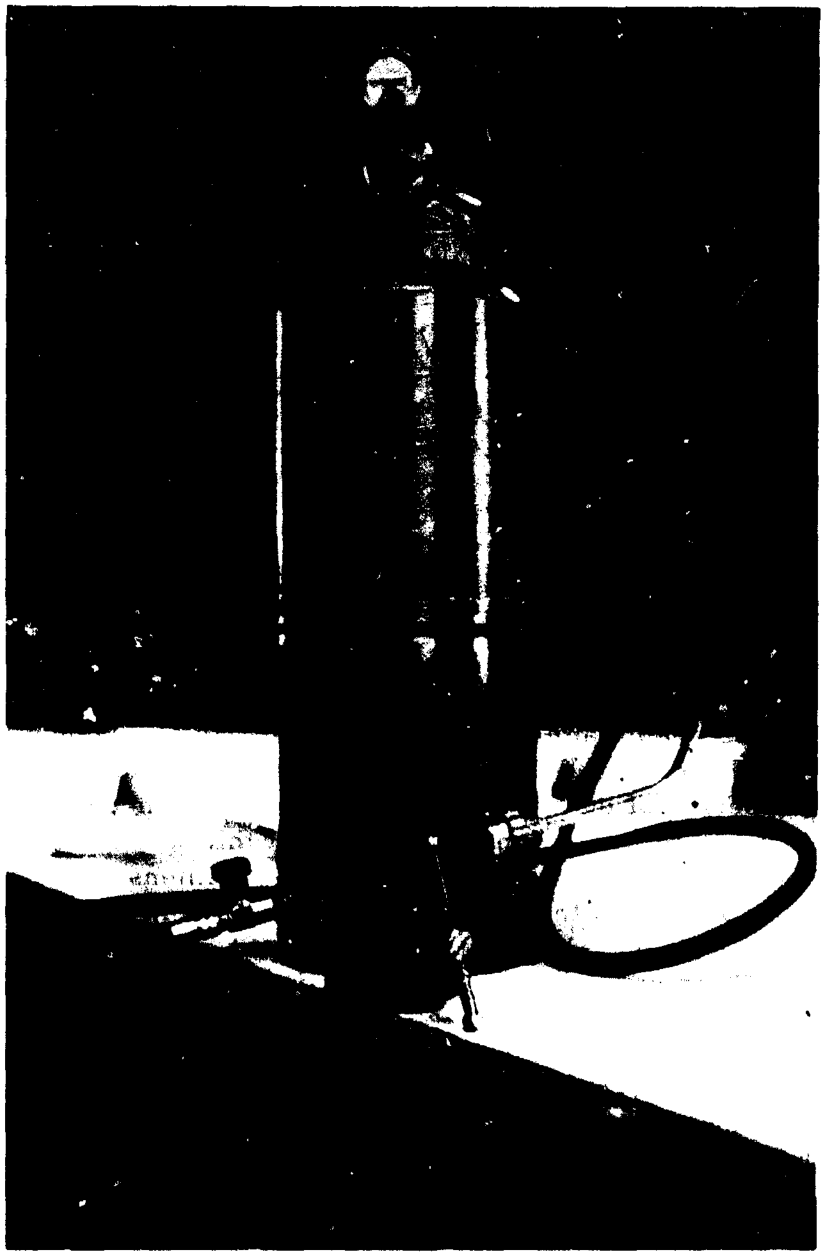

FIGURE 32

Acetylene Equipment Used to Seal Pyrex Tubing Containing Specimens of Serum and Blood Clots from Birds and Mammals

A number 3 torch stem made it possible to seal the hard glass tubing before the wall of the test tube heated to any appreciable extent.

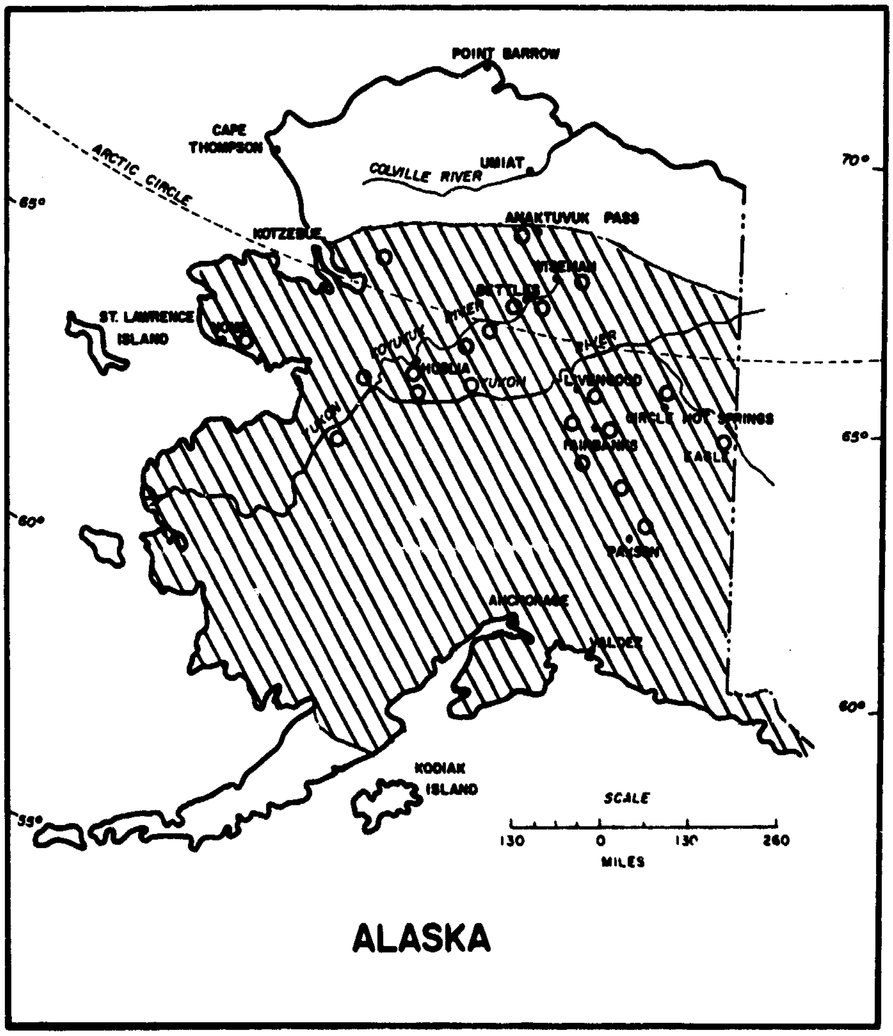

FIGURE 33

Distribution of Culiseta alaskaensis in Alaska

Many of the records are new localities for this species. The most interesting record is the one at Anaktuvuk Pass, the most northerly record known. Dense populations of larvae were found in several pools adjacent to Summit Lake, but no adults were encountered.

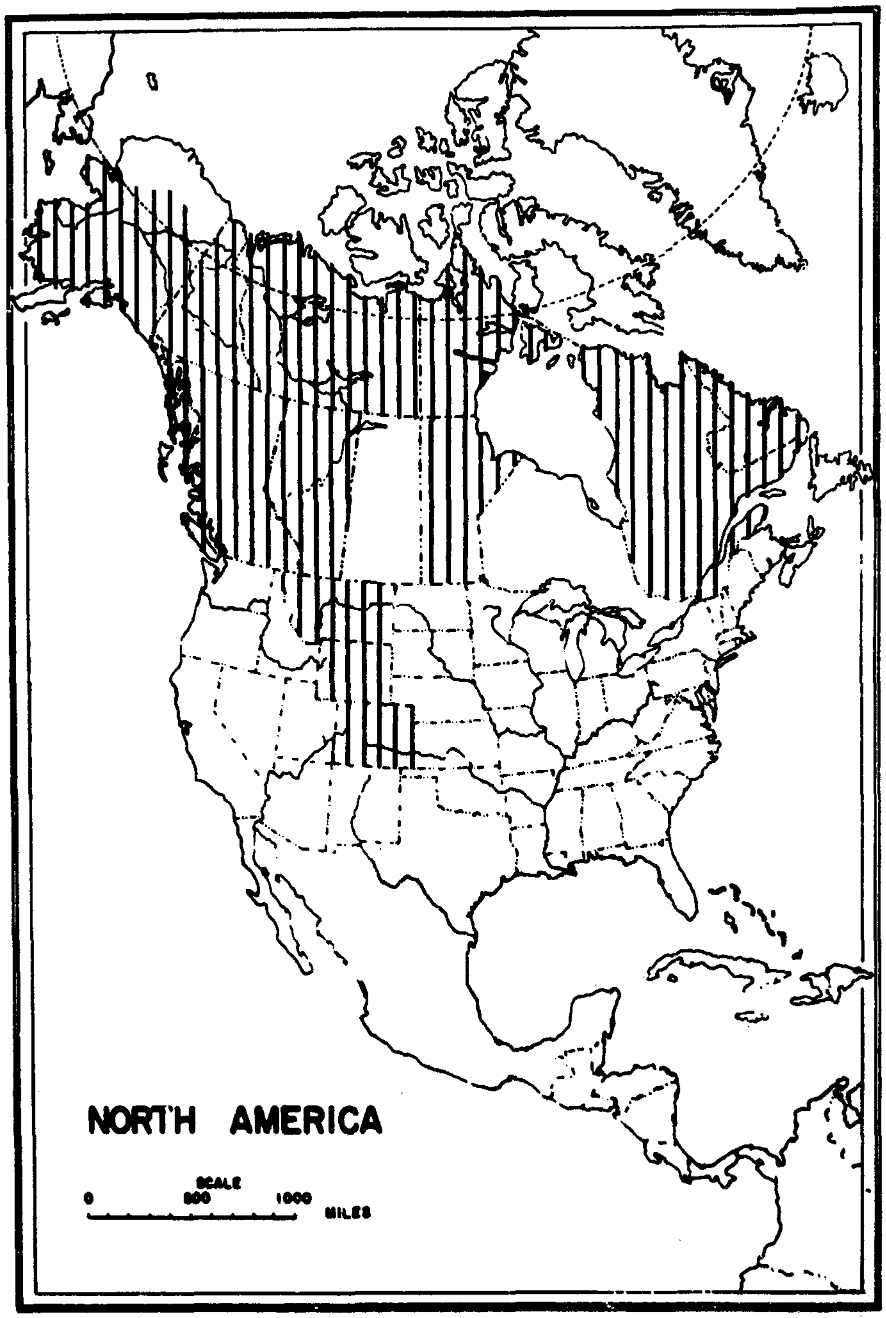

FIGURE 34

Known Distribution of Culiseta alaskaensis
in North America

This species is Holarctic in distribution and is
found widely dispersed in Northern Eurasia.

species as Aedes excrucians in the supposed transmission studies of filarial worms to porcupines and hares, are not valid. For example, he reported that third stage larvae were found in Aedes excrucians by dissection, and therefore he felt that they were vectors of this worm to the hare. I do not deny that Highby saw developmental forms of the worm in the thoracic muscles of the mosquito, but he did not attempt to have the mosquito feed a second time and transmit the organisms into known uninfected animals. It is one thing to get development of organisms within an insect and an entirely different matter to have the insect transmit them to another animal. From my observations of the feeding habits of Aedes excrucians and other mosquitoes, you can manipulate them in the laboratory and have them obtain a second blood meal; apparently, this seldom occurs in nature. Reference is made here to our studies utilizing sweep nets adjacent to our biting study areas in an attempt to get a cross section of the mosquito populations. Recall that less then 1/2 of 1% of some 40,000 mosquitoes captured in this manner had had a previous blood meal!

The only tick known to occur in the central portion of Alaska is the one already mentioned, H. leporis-palustris, which occurs on the snowshoe hare and to some extent upon the gallinaceous birds such as the various species of ptarmigan. It does not bite man and therefore would be of indirect importance. I have two records of Dermacentor andersoni, one from Fairbanks on a dog that was known to have been brought from the Pacific Northwest two weeks previously and one from Cape Thompson. I presume that this tick was packed in some of the field gear of the crews working on Project Chariot. Farther to the south, particularly in the southeastern portion of Alaska, Ixodes angustus is found in reasonable numbers upon various species of rodents. This tick is Holarctic and I think ought to be investigated. Such diseases as the Powassan virus mentioned earlier probably came into North America from the Bering land bridge with the mammal stocks that invaded the Nearctic region from the Eurasian continent. It seems entirely feasible that they would bring many of their diseases with them, and it is known that they have brought many of their ectoparasites. (See Volume I of this report dealing with Alaskan Siphonaptera.)

Miscellaneous observations have been made upon the feeding habits of the black flies (white socks) and the heleids (punkies or no-see-ums). However, time has not been sufficient to have all of these specimens sorted out and sent to specialists. The feeding habits of these two groups merit considerable investigation in the future.

APPENDIX

CHECK LIST OF ALASKAN HEMATOPHAGOUS ARTHROPODS

It is thought that a check list of the hematophagous arthropods occurring in Alaska ought to prove useful. A similar list was prepared by Gordon Gill some years ago and has needed revision for some time.

To my knowledge neither species of Dermacentor is endemic to Alaska, but both have been accidently introduced. With the rotation of personnel and their pets, I would not be surprised if either one or both species became established in parts of Alaska in the not too distant future.

Little is known about the feeding habits of the Simuliidae and Heleidae. There are times when these two groups of Diptera are more bothersome than the mosquitoes. Certainly one's reaction to the bite is far greater than that experienced from contact with mosquitoes.

TICKS

Dermacentor andersoni Stiles
Dermacentor variabilis Say (possibly an erroneous record)
Haemaphysalis leporis-palustris (Packard)
Ixodes angustus Neumann
Ixodes signatus Birula
Ixodes uriae White

PARASITIC MITES

Dermanyssus gallinae (De Geer)
Haemogamasus alaskensis Ewing
Haemogamasus ambulans (Thorell)
Haemolaelaps glasgowi (Ewing)
Hirstionyssus isabellinus (Oudemans)
Laelaps alaskensis Grant
Laelaps Kochi Oudemans
Laelaps multispinosus Banks
Trombicula alaskensis Brennan and Wharton
Trombicula microti Ewing

ANOPLURA

Antarctophthirus callorhini (Osborn)
Antarctophthirus trichechi (Bohemann)
Echinophthirius horridus (von Olfers)

Enderleinellus nitzschi Fahrenholz
Enderleinellus suturalis (Osborn)
Hoplopleura acanthopus (Burmeister)
Hoplopleura sciuricola Ferris (on red squirrels)
Linognathus setosus (von Olfers)
Neohaematopinus laeviusculus (Grube)
Pediculus humanus Linnaeus
Phthirus pubis (Linnaeus)
Polyplax alaskensis Ewing
Polyplax auricularis Kellogg and Ferris
Proechinophthirius fluctus (Ferris)

SIPHONAPTERA

Pulicidae
Hoplopsyllus glacialis lynx (Baker)

Hystrichopsyllidae
Nearctopsylla brooksi (Rothschild)
Nearctopsylla hyrtaci (Rothschild)
Rhadinopsylla sp.
Corrodopsylla c. Curvata (Rothschild)
Catallagia charlottensis (Baker)
Catallagia dacenkoi fulleri Holland
Delotelis hollandi Smit
Epitedia wenmanni (Rothschild)

Ischnopsyllidae
Myodopsylla gentilis Jordan and Rothschild

Leptopsyllindae
Peromyscopsylla ostsibirica longiloba (Jordan)
Amphipsylla marikovskii ewingi Fox
Amphipsylla sibirica pollionis (Rothschild)
Ctenophyllus armatus terribilis (Rothschild)

Ceratophyllindae
Amphalius runatus necopinus (Jordan)
Ceratophyllus arcuegens Holland
Ceratophyllus balati Rosicky
Ceratophyllus celsus celsus Jordan
Ceratophyllus diffinis Jordan
Ceratophyllus garei Rothschild
Ceratophyllus gallinae (Shrank)
Ceratophyllus idius Jordan and Rothschild
Ceratophyllus lunatus tundrensis Holland
Ceratophyllus niger Fox
Ceratophyllus riparius Jordan and Rothschild

Ceratophyllus scopulorum Holland
Ceratophyllus v. vagabundus (Bohemann)
Dasypsyllus gallinulae perpinnatus (Baker)
Dasypsyllus stejnegeri (Jordan)
Malaraeus penicilliger dissimilis (Jordan)
Megabothris abantis (Rothschild)
Megabothris calcarifer gregsoni Holland
Megabothris groenlandicus (Wahlgren)
Megabothris quirini (Rothschild)
Mioctenopsylla arctica hadweni (Ewing)
Mioctenopsylla traubi Holland and Jellison
Monopsyllus ciliatus protinus (Jordan)
Monopsyllus tolli (Wagner)
Monopsyllus vison (Baker)
Opisodasys keeni (Baker)
Opisodasys pseudarctomys (Baker)
Orchopeas caedens caedens (Jordan)
Orchopeas caedens durus (Jordan)
Oropsylla alaskensis (Baker)
Oropsylla arctomys (Baker)
Oropsylla idahoensis (Baker)
Tarsopsylla octodecimdentata coloradensis (Baker)
Thrassis pristinus Stark

Vermipsyllidae
Chaetopsylla floridensis Fox
Chaetopsylla tuberculaticeps ursi (Rothschild)

CULICIDAE

Eskimoan Biotic Province
Aedes communis (De Geer)
Aedes hexadontus Dyar
Aedes impiger (Walker)
Aedes nigripes (Zetterstedt)
Aedes punctor (Kirby)

Hudsonian Biotic Province
Aedes canadensis (Theobald)
Aedes cataphylla Dyar
Aedes cinereus Meigen
Aedes communis (De Geer)
Aedes decticus Howard, Dyar and Knab
Aedes diantaeus Howard, Dyar and Knab
Aedes excrucians (Walker)
Aedes fitchii (Felt and Young)
Aedes hexodontus Dyar

Hudsonian Biotic Province (cont' d)

- Aedes impiger (Walker)
- Aedes implicatus Vockeroth
- Aedes intrudens Dyar
- Aedes nigripes (Zetterstedt)
- Aedes pionips Dyar
- Aedes pullatus (Coquillett)
- Aedes punctor (Kirby)
- Aedes riparius Dyar and Knab
- Aedes stimulans (Walker)
- Anopheles earlei Vargas
- Culex territans Walker
- Culiseta alaskaensis (Ludlow)
- Culiseta impatiens (Walker)
- Culiseta morsitans (Theobald)

Sitkan Biotic Province

- Aedes aboriginis Dyar
- Aedes cinereus Meigen
- Aedes communis (De Geer)
- Aedes excrucians (Walker)
- Aedes pionips Dyar
- Aedes pullatus (Coquillett)
- Aedes punctor (Kirby)
- Culiseta alaskaensis (Ludlow)
- Culiseta impatiens (Walker)
- Culiseta incidens (Thomson)
- Culiseta morsitans (Theobald)
- Culiseta particeps (Adams)

HELEIDAE

- Culicoides alaskensis Wirth
- Culicoides cockerellii (Coquillett)
- Culicoides obsoletus (Meigen)
- Culicoides tristriatulus Hoffman
- Culicoides unicolor (Coquillett)
- Culicoides yukonensis Hoffman (very abundant in the interior, probably a complex of species)

SIMULIIDAE

- Cnephia emergens Stone
- Cnephia eremites Shewell
- Cnephia minus (Dyar and Shannon)
- Cnephia mutata (Malloch)
- Cnephia saileri Stone
- Cnephia sommermanae Stone

SIMULIIDAE (cont'd)

Gymnopais dichopticus Stone
Gymnopais holopticus Stone
Prosimulium alpestre Dorogostajskij, Rubzov and Vlasenko
Prosimulium borealis Malloch
Prosimulium decemarticulatum (Twinn)
Prosimulium dicum Dyar and Shannon
Prosimulium fulvum (Coquillett)
Prosimulium hirtipes (Fries)
Prosimulium onychodactylum Dyar and Shannon
Prosimulium pleurale Maloch
Prosimulium travisi Stone
Prosimulium ursinum (Edwards)
Simulium aureum Fries
Simulium baffinense Twinn
Simulium bicornis Dorogostajskij, Rubzov and Vlasenko
Simulium furculatum Shewell
Simulium gouldingi Stone
Simulium latipes (Meigen)
Simulium pugetense (Dyar and Shannon)
Simulium arcticum Malloch
Simulium corbis Twinn
Simulium decorum Walker
Simulium hunteri Malloch
Simulium malyschevi Dorogostajskij, Rubzov and Vlasenko
Simulium meridionale Riley
Simulium nigricoxum Stone
Simulium rubtzovi Smart
Simulium rugglesi Nicholson and Mickel
Simulium tuberosum (Lundstroem)
Simulium venustum Say
Simulium vittatum Zetterstedt

TABANIDAE (definitely incomplete)

Atylotus insuetus (Osten Sacken)
Chrysops carbonaria Walker
Chrysops furcata Walker
Chrysops nigripes Zetterstedt
Chrysonzona americana (Osten Sacken)
Tabanus affinis (Kirby)
Tabanus astuta (Osten Sacken)
Tabanus boreus (Stone)
Tabanus epistates (Osten Sacken)
Tabanus frontalis (Walker)
Tabanus illota (Osten Sacken)

TABANIDAE (cont'd)

Tabanus septentrionalis (Loew)
Tabanus sexfasciata (Hine)
Tabanus sonomensis (Osten Sacken)

RHAGIONIDAE

Symphoromyia atripes Bigot

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The following is a bibliography pertinent to the cold-hardiness of insects. Before we knew the biology of Culiseta alaskaensis, we had anticipated that it was exposed to the rigorous changes in climate during the winter season. However, we found this was not so, and our preliminary attempts to see if glycerol appeared in the hemolymph of the insect at the temperatures of 16° to 20° F were negative. In our studies, we were unable to obtain survival of the adult mosquito at temperatures beyond 0° F for more than a few days at a time. Until the overwintering habitat was found and its ecology understood, it was thought that our method of cooling the insects had not been satisfactory. However, personal communication with Dr. R. W. Salt has indicated that in his extensive studies of cold-hardiness of insects he was never able to get mosquitoes to supercool below +10° F. According to the literature, insects must survive lower temperatures than this before appreciable quantities of glycerol compounds are formed. This substance was not detected by either the paper or gas chromatographic methods when working with the hemolymph of Culiseta alaskaensis.

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13. ABSTRACT Feeding habits of mosquitoes of the taiga and tundra were studied. Greater emphasis was given to those of the taiga, however, because of the longer mosquito season and the greater variety of genera and species present. Using an exposed area of human forearm (54 square inches) and a similar area of shaved rabbit abdomen, biting records were compiled. Mosquitoes were collected by aspirator after the proboscis was fully inserted. Twice as many mosquitoes were collected from the human as from the rabbit, with Aedes excrucians, A. punctor, A. intrudens and A. pionips predominating in the order given. A tower was built with platforms at 6-foot intervals up to 42 feet, to study vertical distribution and host preference. Domestic chickens, white laboratory rabbits and varying hares, along with empty control boxes, were placed at the various heights. Approximately 80% of the 10,722 specimens obtained were collected in the first 18 feet. The percentages of mosquitoes that were engorged when collected from the bait boxes were as follows: chickens, 18.2%; white rabbits 70%; and varying hares, 92%. Through field observations and laboratory studies, small rodents (microtines) and passerine birds are not thought significant sources of blood meals, but hares, ground squirrels and larger mammals are. Using insect nets, 46,123 specimens were collected in the vicinity of the tower, both from vegetation and aerially up to height of 6 feet. Only six showed evidence of a recent blood meal. Evidence indicates that most subarctic mosquitoes take but one blood meal, a fact of

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Diptera						
Haematophagus arthropods of Alaska						
host preference						
zoonoses						
mosquitoes						

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considerable importance when considering them as vectors of zoonoses. Studies of the natural history of *Culiseta alaskaensis* indicated that the unfed adult females overwinter close to the ground in dense growths of grass underneath the snow cover where the temperature range is from 16 - 20° F. In the laboratory, *C. alaskaensis* lived only about one week at 0° F. Chromatographic studies did not reveal the presence of glycerol compounds in the hemolymph.